PARASITOLOGY

THE MACMILLAN COMPANY
NEW YORK · BOSTON · CHICAGO · DALLAS
ATLANTA · SAN FRANCISCO

MACMILLAN & CO., LIMITED
LONDON · BOMBAY · CALCUTTA
MELBOURNE

THE MACMILLAN CO. OF CANADA, LTD.
TORONTO

A LABORATORY GUIDE TO THE STUDY OF

PARASITOLOGY

BY

W. B. HERMS

UNIVERSITY OF CALIFORNIA, BERKELEY, CALIFORNIA

New York

THE MACMILLAN COMPANY

1913

Ka

Set up and electrotyped. Published May, 1913.

PRESS OF T. MOREY & SON,
GREENFIELD, MASS., U. S. A.

FOREWORD

With the rapid growth of Parasitology there is also a growing demand for laboratory instruction in this field. The author's greatest desire during the time that he has been engaged in teaching this subject has been to place the work upon a good systematic footing, giving it proper rank with other phases of applied biology. The following exercises are based upon several courses in Parasitology (now merged into two) that have been given by the author at the University of California during the past four years, including two summer sessions. Each exercise has had careful testing in the laboratory and is practical.

The aim of this Guide is to give the student a wide practical view of the field so that he might have a fair grasp of the general subject in its application to the health and well-being of man and beast. The exercises are in sufficient detail so that the student is enabled to continue work on some specific group or species if he so chooses.

The exercises are arranged to provide sufficient matter for a laboratory session requiring from two and a half to three hours for each. A number of the exercises are divided into two or three parts, and this may be useful in cases where less time is available. The two standard courses given at the University of California upon which these exercises are based are Human Parasitology (first half year) and Veterinary Parasitology (second half year), each with three lectures per week and two laboratory sessions of from 2½ to 3 hours.

The author wishes to gratefully acknowledge the very able assistance rendered by Mr. A. B. Shaw, Jr., in the preparation of this laboratory guide.

W. B. H.

BERKELEY, CALIFORNIA,
August 5, 1912.

CONTENTS

PART II

HELMINTHOLOGY

PART III

LIFE HISTORY STUDIES ON LIVING PARASITES

INTRODUCTION

The object of the following exercises is to acquaint the student with the commoner animal parasites of man and of the domesticated animals, including insect carriers of disease. In studying the parasites here considered, the student should bear in mind the following statements and make observations accordingly.

A *parasite* can only be a parasite as it lives directly at the expense of another organism, whether plant or animal. This definition leaves few if any animals out of this category, inasmuch as the dependence of animals directly upon other animals or upon plants for food is obvious. But if we restrict this meaning to *position*, living in or upon another animal or plant for purposes of feeding, we come nearer to the thought. But even here there are many organisms which live in or upon living animals or plants, merely sharing their food with them without injuring the host. This we call *commensalism*. Furthermore, organisms feeding in or upon dead bodies would not be termed parasites, except as they also attack or feed upon living tissue, as occurs in certain flesh flies, e. g. the Texas Screwworm fly (*Chrysomia macellaria*), which as a larva may feed upon the flesh of dead or living animals. Thus our definition revolves about the idea of feeding upon *living* organisms, to which should be added that the host must not be killed before at least the developmental period or larval period of the parasite is completed, otherwise the result would be the destruction of the parasite as well as the host. Parasitism then involves slow death to the host, if fatal consequences are at all involved. The definition given by Braun is, viz., "By the term Parasites is understood living organisms which for the purpose

of procuring food, take up their abode temporarily or permanently, on or within other living organisms." This definition will exclude predaceous animals (Raubtiere), which capture their prey alive, and usually kill it outright for purposes of food.

Classes of parasites. Other than the two general classes, *Ectoparasites* (external parasites), and *Entoparasites* (internal parasites), all parasites may be placed in one or another of the following divisions, according to the time spent in or upon the host. *Facultative* parasites have the power of changing from one host to another of a different species, e. g. the cat and dog flea, *Ctenocephalus canis*, which may be found upon the cat, the dog, the rat and man; the rat flea, *Ceratophyllus fasciatus*, upon the rat and upon man; the wood tick, *Dermacentor variabilis*, may be found on nearly all species of domesticated animals and man. *Obligatory* parasites are restricted to one species of host, e. g. the biting bird lice (Mallophaga), which perish sooner or later if transferred to another species of host. *Intermittent* parasites are such as prey upon the host for food, as in the female horseflies (Tabanidæ) attacking horses and cattle for the purpose of sucking blood and leaving the host after a meal. *Transitory* parasites are such as pass part of the life history at the expense of the host, for example, the botflies (Œstridæ) which pass the larval period of development within the body of the host, while the adult botflies are free living and do not attack other animals for food.

Effect of parasitism on the host. That an animal is parasitized does not necessarily involve it in death, not even in great inconvenience, although the parasite is actually living at its expense. The presence of a few bots in the stomach of a horse may not affect that animal in the least, nor would the presence of a few lice on the body of an animal, but with the multiplication of these parasites there will be increased inconvenience to both hosts. The presence of a few maggots in the fleshy part of a sheep's leg might cause little damage, but let these be in the nasal sinuses or at the base of the brain, and the gravity of the

situation will be greatly augmented. Thus the effect of parasitism on the host depends both on the number and position of the parasite.

Effect of parasitism on the parasite. All parasites are more or less specialized in the direction of their habits, e. g. fleas are laterally compressed to effect ease of motion between hairs; lice are horizontally flattened and are provided with strong clasping organs to hold fast to hairs, and both of these examples are wingless and have sacrificed much of the ordinary means of locomotion. Entoparasites are usually provided with specialized hooks, barbs, suckers, etc., for purposes of attachment to the alimentary canal or other organs, e. g. the botfly larvæ, and among the Helminths, the flukes (Trematoda), the tapeworms (Cestoda), etc. Perhaps because of the ease in securing food the sense organs are usually not strongly developed, the eyes may be wanting or very simple. The mouthparts differ in the several groups, depending on their special adaptation of habit. It is interesting to note that the parasitic habit has resulted in the development of structural similarity. This is especially prominent in the clasping structures of the biting and sucking lice, which belong systematically to two different orders, namely, the Mallophaga and the Hemiptera.

Origin of parasitism. Modern parasites are restricted more or less completely to a particular host animal, which would necessitate the deduction that the parasite must have developed its habit after the existence of the host, and in consequence that parasitism must be a recently acquired habit. This thought is further expressed by the study of the life history of the parasite. Invariably the earlier stages point to a free living existence. Perhaps the ancestors of a given group of modern parasites were attracted to the waste food, offal and exudations of certain animals; the search for food may have become simplified; they began living as messmates or commensalists, or as scavengers; the association between the species may have become closer and the eventual line of parasitism completed. This is also borne

out by a study of the nearest allies of a given parasite and members of a given family of parasites, in which the gradation from free living animal to parasite may often be traced. Among the biting lice (Mallophaga) there are species which have the power of running freely, e. g. *Menopon pallidum*, the common hen louse, which may live for a considerable length of time off its host, while other species have become quite sessile, as in the case of the worm-like louse *Menopon titan*, which inhabits the pouch of the pelican. Among the fleas there are also good examples of this gradation in habit and structure, e. g. the human flea, *Pulex irritans*, while it has developed the springing power, is comparatively free to move from place to place, while the hen flea, *Xestopsylla gallinæ*, is quite sessile and holds fast at one point to draw blood much like a tick.

The ectoparasites will be studied first, on account of the greater ease of handling them. In the meantime the student will gain greater efficiency, preparatory to studying the more difficult entoparasites.

DIRECTIONS

The student should provide himself with a hand lens and loose leaf drawing paper and notebook.

Drawings should be made with a hard pencil, preferably 3H. Do not use a fountain pen or soft pencil for this work.

Notes should be taken on each exercise and properly interleaved.

Each exercise will provide enough material for a laboratory session of from 2½ to 3 hours.

Specimens, whether mounted dry, on slides or otherwise prepared must be handled with care.

Special care must be exercised in studying microscopic slides under the compound microscope. Do not crush the specimen by running the objective down upon it.

SUGGESTIONS

Students are strongly urged to be on the "lookout" for cases of parasitism, not only because this lends emphasis to the work in hand, but also because of the scientific importance and value of such observations and collections.

Internal parasites (taken wet) such as tapeworms, roundworms, bots, warbles, etc., may be preserved in 75% alcohol or 4% formaldehyde, preferably the latter. If alcohol is used as a preservative the specimens should be run into the higher grades of alcohol gradually, beginning with 25% and allowing 2 or 3 hours between each change (25%, 35%, 50%, 75%).

Insect specimens may be mounted on pins or points or may also be preserved as above.

PARASITOLOGY

PARASITOLOGY

PART I

MEDICAL ENTOMOLOGY

INSECTS AND DISEASE

DISCUSSION

HOW PATHOLOGICAL CONDITIONS ARE PRODUCED

General considerations. By pathological conditions we would have understood a diseased state of tissue, deranged function or the like,—an abnormal condition of the body. Animal diseases may be produced in many ways, and it is not the object of this exercise to give a complete discussion of even the general principles of pathology, except only in so far as insects are concerned. In this work we cannot merely define those insects as parasites in the usual acceptance of the term as defined by Braun, "living organisms which take up their abode, for the purpose of procuring food, temporarily or permanently, on or within other living organisms," because there are certain insects which are not usually considered as parasites, but are nevertheless the grossest transmitters of diseases, e. g. the housefly, as a transmitter of certain enteric affections.

Insects and arachnids may relate to pathological conditions, whether serious or of little consequence, in one or more of the following ways, first, through *direct infection*, second, through

indirect infection, third, through *internal parasitism*, fourth, through *external parasitism*, and lastly, through *insect venoms*. The same species may fall as legitimately into two divisions, as, for example, the Texas fever tick, which if not infected with the causative organisms of the fever need only be considered as an external parasite, but when the causative fever organisms are present in the tick would relate it also to direct infection.

Direct infection. Direct infection under ordinary conditions can only be produced by an insect or arachnid possessing piercing mouthparts, and here no special order or larger group can well be referred to, inasmuch as closely related insects may have very different mouth structures. The common housefly and the stable fly, for example, belong to the same family, therefore are closely related, yet have very different mouthparts; though both are suctorial, the former is unable to pierce the skin, whereas the latter can do so with ease.

By direct infection is meant the introduction of a pathogenic organism, whether bacterial or protozoan, into the circulation of a higher animal. The Anopheles mosquito is thus related to this manner of transmission, since this insect introduces the malaria parasite directly into the blood stream of man. The same is true of the Stegomyia mosquito and yellow fever, the Glossina flies and sleeping sickness, the horseflies and anthrax, the Texas fever tick and Texas fever, etc. Direct infectors are usually temporary ectoparasites (intermittent parasites), permitting transfer of activity from animal to animal.

While the conditions just discussed are to be referred to direct infection, there is still a possibility for an insect with mandibulate mouthparts or with haustellate mouthparts of non-piercing form to infect an animal as directly as one possessing piercing mouthparts. Thus the housefly may, by means of mouthparts and foot structures, transmit gangrene from an animal thus affected to an animal undergoing surgical operation, or suffering from an open wound. Pustular matter might be transmitted in an equally direct manner.

Indirect infection. This form of infection relates chiefly to enteric diseases in the causation of which the pathogenic organism is deposited upon the food of the higher animal by the insect. Thus the food is first infected, and through this the pathogenic organism is implanted within the alimentary canal of the victim; in this way the insect is concerned only indirectly. The housefly which is quite certainly one of the grossest transmitters of enteric diseases is so only because of accident of habit and structure, feeding as it does indiscriminately upon excrement and upon the food of higher animals. The structure of the proboscis and feet is such as to make it quite difficult not to carry particles of the excrement to the food. Thus if disease producing "germs" are present the result is inevitable.

Insects possessing mouthparts not adapted to piercing the skin (whether biting or sucking) can relate only to this form of infection, and indeed any insect or arachnid may be an indirect carrier by accident. Furthermore insects ordinarily relating only to indirect infection may produce direct infection of certain kinds, where there is access to an open wound; for example, the transmission of gangrene through the agency of the common housefly from a diseased animal to another animal which presents an open wound, cut or sore.

Internal parasitism. There are no insects as far as is known which spend their entire life history in the form of internal parasites. There are, however, a number which pass their larval period (period of growth) within the alimentary canal or in the muscle tissue of higher animals. The best known representatives of this group are the botflies and the warble flies, the former found mainly in the stomach of equine animals, while the latter are found in the muscle tissue of bovine and equine animals, rodents and sometimes man. The damage done by internal parasites is of various kinds; first, disturbed nutrition, and secondly, irritation caused by the burrowing parasites in the muscles or by the attachment of hooks to the intestinal lining for the purpose of prehension.

External parasitism. The most important and most abundant external parasites of man and of the domesticated animals are found among the insects and arachnids. Very serious and often fatal results are due to this form of irritation, and the loss of blood due to an abundance of any blood-sucking species must not be overlooked. External parasites may be either permanent or temporary with relation to their host. The commonest permanent parasites are the biting and sucking lice, which are usually transferred from host to host by close association of mammals while sleeping together, or in close quarters or in copulation; in poultry generally while roosting. While permanent ectoparasites are not so largely concerned in the direct transmission of infectious diseases, certain sucking lice are known to be agents in the transmission of Trypanosomes. The temporary (intermittent) ectoparasites are the most important of all disease carriers, on account of their change of host, dropping off or flying away from one animal to another of the same or a different species. It may well be seen that herein lies the danger of transmitting infectious diseases from animal to animal. The temporary ectoparasites are well represented by the fleas, bedbugs and ticks.

Insect venoms. Another form of irritation is produced by the inoculation of a specific poison into a wound produced by a piercing or stinging insect. Many insects produce severe irritations by their bites, which fact can be accounted for by the presence of a venom-secreting gland, often salivary. The cone-noses or kissing bugs (Reduviidæ) inflict a very painful wound which is aggravated by a poison; other insects produce nettling when handled, e. g. the blister beetles (Meloidæ). Again, the familiar sting of the bee and the wasp is chiefly painful because of the injection of a specific poison.

HOW INSECTS CARRY DISEASE

In the above section we have seen how insects relate to the *causation* of disease. It is obvious that we may view the field from a slightly different angle, i. e. our classification may be based on *transmission* as well.

The simplest way in which insects enter in as a factor in the transmission of disease is through *soiled feet and mouthparts.* Any insect might accidentally become contaminated with infective sputum or fecal matter and in turn might accidentally come in contact with human foods, thus becoming an indirect infector, as already explained. In this connection the normal habit of the insect must be considered, i. e. its breeding habits, food habits and general behavior. Thus the housefly enters in as a factor in the transmission of such diseases as typhoid fever and tuberculosis, because of its normal habits and is a carrier in the simplest possible manner.

A second purely mechanical method of transmission, though more restricted, is by means of a *soiled piercing proboscis*, in cases of certain blood diseases. In the foregoing class the type of mouthparts does not enter as a restrictive factor, but in order that the proboscis may become soiled with blood the mouthparts must be capable of piercing the skin, thus coming in contact with the blood and its contained parasites, if present. The inoculation of the second host may be purely mechanical. Insects that belong to this class of carriers ordinarily have heavy piercing mouthparts drawing considerable blood, are intermittent parasites, and often go from host to host within a short time. The horsefly (Tabanus) is a good representative of this class in its chance relation to anthrax.

A still more highly specialized method is involved in the transmission of bubonic plague by fleas. In this case the carrier has piercing mouthparts, is bloodsucking and an intermittent parasite, but it does not inoculate the second host by means of a soiled proboscis as far as is known. The plague bacilli when

taken into the stomach of the flea increase in numbers and do not become attenuated, but pass out with the feces or even in undigested blood per anum in a virulent condition; the direct inoculation must be through a "rubbing in" process on the part of either the host or the flea.

The greatest complexity is involved in such cases in which the *carrier is a necessary factor in the life history of the pathogenic organism*, e. g. the Anopheles mosquito has piercing mouthparts, is bloodsucking, and an intermittent parasite, in which a given period of time must elapse before it can transmit the causative organism of malaria, once it has become infected. This period of time corresponds to the time required for the Plasmodium to pass through its sexual cycle and find its way back into the proboscis, i. e. into the salivary glands, ready to be reinoculated.

INSECT MOUTHPARTS

Importance of mouthparts. It becomes evident that an insect possessing mouthparts capable of piercing the skin of the higher animals must be looked upon as a possible carrier of blood infection, although it may in actual experience never attack other animals. If the insect is provided with mouthparts of the usual biting type it cannot relate to infection introduced through the circulation except by rare accident through a previously inflicted open wound.

The mosquito would be harmless as far as malaria and yellow fever are concerned if the mouthparts were of the mandibulate or biting type. These insects together with certain other species such as the stablefly, *Stomoxys calcitrans*, the tsétsé flies and the ticks are important because of the power which they possess of piercing the skin of higher animals and introducing parasitic organisms into the blood. The housefly on the other hand cannot introduce organisms directly into the circulation because its mouthparts are not of the piercing type. These creatures are attracted by and often breed in excrementous matter, are then

attracted to the food of human beings, and introduce thereon the pathogenic organisms from their mouthparts and feet.

The actual measures of control are quite often dependent on a knowledge of the mouthparts of the insect concerned.

Inadequacy of old systems. In the study of Medical Entomology it is no longer sufficient to divide the insects into only two groups as based on the mouthparts, namely, Mandibulate, or biting, and Haustellate, or sucking. This fact becomes clearer when it is considered that the housefly (*Musca domestica*) and the stablefly (*Stomoxys calcitrans*) both have sucking mouthparts and belong to the same family, Muscidæ, hence are systematically very closely related, yet from the standpoint of disease transmission are widely different. By virtue of the piercing structures composing the mouthparts of the stablefly it relates to direct infection, while the housefly's proboscis, quite ineffective as a piercing structure, relates it to indirect infection, —not however of less importance as a disease transmitter.

Because of the deficiency of the older systems of mouthpart classification the following types will be considered.

Types of insect mouthparts. The following types of mouthparts may be recognized:

1. *Orthopteron type*,—biting or chewing structures, as in the grasshopper.

2. *Physopodan type*,—transitional mouthparts of biting form but functionally serving as suctorial organs, as in the thrips.

3. *Hemipteron type*,—suctorial organs enclosing three or four piercing setæ closely ensheathed within the labium, as in the cone-noses.

4. *Dipteron type*,—suctorial organs; no special example being available for the entire order, the following subtypes must be recognized:

A. First subtype—Mosquito, loosely ensheathed piercing bristle-like structures, six in number.

B. Second subtype—Horsefly, piercing blade-like structures, six in number, loosely ensheathed.

C. Third subtype—Stablefly, closely ensheathed heavy piercing structures, two in number.

D. Fourth subtype—Housefly, suctorial muscular proboscis, but not suited to piercing.

5. *Hymenopteron type*—suctorial, lapping form, as in the honeybee and ant, mandibles modified for portage and combat.

6. *Lepidopteron type*—suctorial, coiled tube form, as in the cabbage butterfly.

EXERCISE 1

A Study of Insect Mouthparts

A. *Orthopteron type.*

To illustrate this type either the grasshopper or the cockroach may be used, but since the former is more easily obtainable and can be handled more satisfactorily it will serve this purpose very well. This type, the mandibulate or biting, is the generalized or primitive form, and will serve as a basis for later comparisons and derivations.

If the head of the grasshopper is viewed from the side and again from the front the relative position of the parts will be better understood.

Separating the structures composing the mouth of the grasshopper, the following pieces will be observed. In front, low down on the head, hangs the *labrum*, or upper lip, attached to the *clypeus*, easily lifted as one would raise a hinged lid, the hinge line being at the lower part of the sclerite known as the clypeus.

The labrum functions as does the upper lip in higher animals, in that it draws the food toward the mandibles. In this the labrum is greatly aided by a rough toothed structure called the *epipharynx*, which forms the inner lining of the labrum and the clypeus. Because of the close association of these two structures they are often referred to as a double organ, the *labrum-epi-*

pharynx. Removing the labrum the pair of heavy black opposable jaws, or *mandibles*, is exposed. These are biting structures *par excellence.* They are toothed and movable laterally, instead of vertically as in the vertebrates. Dislodging the mandibles brings the pair of *maxillæ*, or accessory jaws, into view. These organs are also called *first maxillæ.* These are composite structures, each separable into *lacinia, galea, palpus, cardo* and *stipes*, which should be carefully noted, inasmuch as they undergo great modification in the remaining types of mouthparts. The two supporting sclerites are called the cardo (basal), and stipes (the second) while the distal lobes are called, 1, the maxillary palpus (a jointed structure), 2, the galea (median and fleshy), 3, the lacinia (inner and toothed, capable of aiding in comminuting food).

Underneath the maxillæ and forming the floor of the mouth, lies the lower lip, or *labium*, a double structure, frequently called the second maxilla. On the same plan as the maxillæ, the labium consists of a basal sclerite, the *submentum*, followed by the *mentum*, upon which rest the *labial palpi* (a pair of outer, jointed structures, to the right and left) and the *ligulæ* (a pair of straplike pieces which together correspond to the upper lip). The labium is, like the maxillæ, also subject to much modification.

The fleshy organ still remaining in the mouth cavity after the parts just described have been removed, is the tongue, or *hypopharynx*, functionally comparable to the tongue of vertebrates, an organ of taste.

Draw side and front view of grasshopper's head; also *make a drawing* of each mouthpart separately, *labelling* all parts.

B. *Hymenopteron type.*

In this type the two general classes of mouth structures, the Mandibulate and Haustellate, find a rather strong development in the same species, though the former structures are not concerned as comminuting organs with respect to food. The honey-

bee will serve as a representative species. Examine mounted specimens of mouthparts as well as complete heads. The *labrum*, above, is narrow and quite simple. The *mandibles* are easily distinguishable and are useful wax implements. In ants the mandibles are highly efficient carrying organs and weapons of defense. The *maxillæ* form the lateral conspicuous wings of the suctorial parts; the lacinia and galea are fused into one piece, and the *maxillary palpi* are quite minute. The *labium* is represented by the long structures to the right and left of the middle tube, which is probably the *hypopharynx*. The hypopharynx terminates in a spoon or *bouton*, which completes the lapping character of the type.

Draw and *label* parts.

EXERCISE 2

Insect Mouthparts (cont.)

C. *Hemipteron type.*

A very different sort of organ than the above described types is found in the Hemiptera. Here the *labium* forms a prominent beak, which is usually three (rarely one or four), jointed, and telescopic. Examine mounted specimens of mouthparts of a cone-nose,—Reduviidæ. The beak encloses a pair of *mandibles*, often provided with cruel barbs at the distal end, and the *maxillæ*, all bristle-like, and of great efficiency in piercing the skin. The maxillæ are more or less completely joined, forming a tube, so that often only three bristles or stylets can be seen on examination. The *labrum* is quite short and inconspicuous.

Draw side views of the head of the cone-nose, showing the proboscis and stylets. *Label* the parts.

D. *Lepidopteron type.*

This type, represented by the commoner butterflies and moths, is typically a coiled, sucking tube, capable of great elongation.

Taking the cabbage butterfly (*Pieris rapæ*) as an example, the *labrum* is seen to be greatly reduced, the *mandibles* absent. The mandibles may be weakly present in the lower Lepidoptera. The maxillæ are apparently only represented by the *galea*, which by the close approximation of their inner grooved surfaces form the proboscis, long and coiled. The double structure of the proboscis can easily be demonstrated by manipulation. The labium is represented by the *labial palpi*.

Draw and *label* parts.

E. *Dipteron type.*

a. First subtype, the *mosquito*. The more generalized type of Dipteron mouthparts is found in the mosquito, hence here we find the maximum number of stylets or bristles, representing the parts of the more generalized types, loosely ensheathed in the elongated *labium*, the whole forming the prominent beak, or proboscis. The identity of the six stylets is not well established, though it is generally accepted that they represent the two *mandibles*, the two *maxillæ* (distinctly serrated distally), the *hypopharynx*, and the *labrum*. The *palpi* are conspicuous structures in all mosquitoes, and are useful as a means for classification. These represent the maxillary palpi of the grasshopper while the pair of flattened lobe-like organs forming the distal portion of the proboscis are said to represent the labial palpi, and are called the *labella*.

Draw and *label* parts.

EXERCISE 3

Insect Mouthparts (cont.)

E. *Dipteron type* (cont.).

b. Second subtype—the *horsefly*. While retaining the same number of parts as in the mosquito, this subtype is distinctly characterized by the flattened blade-like condition of these

organs, rather than the bristle-like or stylet form of the first subtype. That these mouthparts serve quite largely as cutting structures is evident from the large wound made and the quantity of blood drawn by the "bite" of a horsefly, especially one of the larger species, such as the black horsefly (*Tabanus atratus*). The *labium* is the conspicuous median portion, loosely ensheathing the blades, and terminating in large *labella*. The *mandibles* are distinctly flattened and sabre-like, while the *maxillæ* are narrower and provided with conspicuous *palpi*. The *hypopharynx* and *labrum-epipharynx* are both lancet-like. In the male these piercing parts are very weakly developed, and are not useful as weapons of attack.

Draw and *label* parts.

c. Third subtype—the *stablefly*. This subtype represents a group of piercing flies in which the mouthparts are distinctly specialized, and show, together with the next subtype, to what extent these structures may become differentiated within the same family of insects.

The proboscis at rest is carried at the position of a bayonet at charge, and is therefore provided with a prominent knee or elbow, which portion is highly muscular. This conspicuous organ is the *labium*, terminating in the *labella*, which are provided with a complex series of cutting and adhesive structures. Within the folds of the labium and easily removable through the upper groove lie two sharp, heavy, bristle-like structures, the *labrum*, the uppermost and heavier stylet, and the *hypopharynx*, a lower and weaker structure, the two forming, as in other Muscidæ, a sucking tube supported within the folds of the labium. The *maxillary palpi* are less prominent than in the other Muscidæ, but are similarly located, at the proximal end of the proboscis.

Draw and *label* parts.

d. Fourth subtype—the *housefly*. Here the prominent fleshy proboscis consists mainly of the *labium*, which terminates in a pair of corrugated rasping organs, the *labella*, and is attached in

knee-like form to the elongated head. The entire mass is highly muscular, and may either be protruded, as in feeding, or quite largely withdrawn, while at rest. Lying on top of the grooved labium is the inconspicuous prolonged spade-like *labrum*, which forms with the *hypopharynx* a sucking tube, supported by the labium, which latter also encloses the salivary canal. By an examination of the labrum it will be seen that it forms a kind of convex cover to the concaved hypopharynx, thus giving rise to a food tube. The maxillæ have evidently become fused with the fleshy knee of the proboscis, and only the prominent *maxillary palpi* remain.

Draw and *label* parts.

EXERCISE 4

Internal Anatomy of an Insect

It is important that the student familiarize himself with the internal anatomy of an insect, with special reference to the digestive system and its accessory structures, such as the salivary glands. For this purpose a grasshopper is to be dissected, owing to ease of manipulation. If the student has time it is recommended that the internal anatomy of a stablefly be studied for the sake of comparison.

With fine pointed needles or scissors open the dorsal abdominal wall, separating the right and left sides to expose the intestine. Small pins will be found convenient to pin down the parts and thus allow more freedom in working. The insect should be dissected under water in a dish with a paraffin floor.

A. *Determine* the following parts, *drawing* and *labelling* the same.

a. The *mouthparts*, without reference at this time to details; these have already been studied.

b. The *œsophagus*, a straight tube leading from the *pharynx* to the *crop*.

c. The opening of the *salivary ducts*, emptying into the œsophagus, and the pair of *salivary glands*.

d. The *crop*, or short food-receiving chamber, emptying into the *stomach* proper, a longer cylindrical chamber, anterior to which are the *gastric cæca*, and posterior the hair-like *malphigian tubules*.

e. The intestine, a long, slender, coiled tube posterior to the stomach, consisting of three parts, the *ileum*, *colon* and *rectum*, the latter a short straight tube ending in the *anus*.

B. If time remains the student is urged to study the internal anatomy of a stablefly for purposes of comparison.

a. Note the connection between the blood-sucking proboscis and the œsophagus.

b. How does the crop compare with the crop of the grasshopper? Note its adaptation to the storage of blood.

EXERCISE 5

Comparative Study of the Biting and Sucking Lice

Use for this exercise slide mounts in balsam of *Hæmatopinus piliferus*, the sucking louse of the dog, and either *Trichodectes latus*, the biting louse of the dog, or *Trichodectes scalaris*, the biting louse of cattle.

The biting lice belong to the order Mallophaga, while the sucking lice belong to the Order Hemiptera, Family Pediculidæ. These two groups of parasites are not always easily distinguishable without the use of a compound microscope. The bodies of both are flattened dorso-ventrally, and in both wings are absent.

With a mounted specimen of each in hand, *examine* them under a compound microscope (low power) and determine the following characters, *drawing* each specimen. Your drawings should be large enough to cover at least half a page of ordinary notebook size.

a. *Compare* the *head, thorax* and *abdomen*, noting the relatively small thorax as compared with that of the housefly, for example.

b. The *appendages* differ how? Note the claws of each species and explain the difference on the basis of the relative activity of the insects. The sucking lice generally and many species of the biting lice have heavy clasping structures.

c. Determine the position of *antennæ* and *eyes*, if present.

d. Study the *mouthparts* of each species. Note the rather sharp *mandibles* of the biting louse. Where are the mouthparts located? Observe the *proboscis* of a sucking louse in which that organ is protruded. What is the position of that organ when the insect is not actively feeding?

e. Search for traces of *blood* in the *stomachs* of both species.

EXERCISE 6a

Order Mallophaga (Bird Lice)

Anatomical Study.

Using a slide mount of the common hen louse (*Menopon pallidum*) *determine* the following parts, making a large *drawing* of the specimen:

a. *Head, thorax, abdomen.*

b. *Antennæ,*—are they clavate (club-shaped) or capitate (ending in a distinct knob)? *Determine* number of segments.

c. *Mandibles.*

d. *Eyes.*

e. *Temples*, posterior lateral portions of the head.

f. *Ocular emarginations*, a bending in of the lateral margins of the head just in front of the eyes.

g. *Sternal markings*,—blackish markings, bars or spots, on the ventral aspect of the thorax. (May not be visible.)

h. *Tarsal claws*, whether paired or single, whether strongly adapted for clasping hairs and feathers or not.

EXERCISE 6b

Order Mallophaga (Bird Lice)

Systematic Study.

As representatives of the families of the Order Mallophaga the following are available:

A. Suborder Ischnocera.

a. Family Trichodectidæ.

Genus Trichodectes, examples, *T. latus* and *T. scalaris.*

b. Family Philopteridæ.

Genus Lipeurus, example, *L. polytrapezius*, the long turkey louse.

Genus Goniodes, examples, *G. stylifer* of the turkey and *G. dissimilis* of the hen.

B. Suborder Amblycera.

a. Family Gyropidæ.

Genus Gyropus, examples, *G. sp.* from ground-squirrel.

b. Family Liotheidæ.

Genus Menopon, examples *M. pallidum*, the common hen louse and *M. biseriatum*, also from hens.

Genus Trinoton, example, *T. luridum*, the duck louse.

As representatives of the Trichodectidæ and Liotheidæ have previously been drawn, draw one example each of the two remaining families, Philopteridæ and Gyropidæ.

EXERCISE 7a

Order Hemiptera, Suborder Parasita, Family Pediculidæ

THE SUCKING LICE OF MAMMALS

Anatomical Study.

The suctorial lice are wingless, as are the biting lice, and the two may be confused, if attention is not paid to the structure of

the mouthparts. Furthermore, the heads of members of the former order are usually much more elongate in proportion to the size of the body than is the case in the Mallophaga. The claws of the Parasita are also strongly developed for clasping and clinging to hairs.

Examine a mounted specimen, using the hog louse (*Hæmatopinus suis*) as an example of the order, and note the distinctions above mentioned.

The *proboscis* of the sucking louse is fleshy and unjointed, surrounded at its base by a *circlet of barbs*, and is in the form of an extensile tube provided with lancets. The *legs* are short and stout, and the *tarsus* is provided with a strong *opposable claw*.

Draw the specimen, showing the general structure.

EXERCISE 7b

ORDER HEMIPTERA, SUBORDER PARASITA, FAMILY PEDICULIDÆ

Systematic Study.

The Suborder Parasita includes two families, only one of which needs to be considered here. The other family is Oriental, and is found solely on bats.

Family Pediculidæ.

Genus Pediculus, examples, *P. capitis*, the head louse of man, and *P. vestimenti*, the body louse of man.

Genus Phthirius, example, *P. inguinalis*, the crab louse of man.

Genus Hæmatopinus, examples, *H. piliferus*, the sucking louse of the dog, *H. suis*, of the hog, *H. macrocephalus*, the horse louse, and *H. spinulosus*, the sucking louse of the rat.

Examples of the Genus Hæmatopinus having been drawn previously, *make* large *drawings* of one example each of the genera Pediculus and Phthirius.

EXERCISE 8a

The Bedbug

ORDER HEMIPTERA, FAMILY ACANTHIIDÆ

A. *Characteristics of Hemiptera.*

The Hemiptera usually possess two pairs of wings (except, e. g. the Acanthiidæ and Pediculidæ), the front wings (wing-covers) in the Hemiptera-Heteroptera are partly leathery, and membranous at the apices. The mouthparts, as already studied, are piercing, suctorial, typically three-jointed, closely ensheathing three or four setæ.

B. *Characteristics of Acanthiidæ.*

A group of wingless insects with extremely flattened bodies, giving off a pungent odor. The color is reddish brown. Antennæ are four-jointed.

a. *Examine* a mounted specimen of *Cimex lectularius*, the common bedbug, for the above indicated characteristics. *Draw* the specimen.

EXERCISE 8b

The Cone-noses

ORDER HEMIPTERA, FAMILY REDUVIIDÆ

A. *Characteristics of Reduviidæ.*

This is a group of predaceous insects, fore wings partly leathery, distal portion membranous. The head is long and joined to the body by a slender neck. The tip of the head is cone-shaped, with a three-jointed heavy rostrum which curves underneath the body. The antennæ are long and slender. The legs are prominent and give the insect a sprawled out appearance.

B. *Examine* the following common species, noting color and color markings in particular. *Draw* side view of (a), and dorsal view of (d).

a. *Melanolestes picipes*—the China bedbug.

b. *Melanolestes abdominalis*—also called the China bedbug.

c. *Reduvius personatus*—the Eastern kissing bug.

d. *Rasahus biguttatus*—the two spotted corsair.

e. *Conorhinus sanguisuga*—the blood-sucking cone-nose.

EXERCISE 9

Mosquitoes

ORDER DIPTERA, FAMILY CULICIDÆ

With specimens of mosquitoes before you, study them with a hand lens for (A) and with a compound microscope for (B).

A. a. One pair of membranous *wings*.

b. The *legs* are long and slender. Note the following parts, *femur*, *tibia*, and *tarsus*, the latter segmented.

c. On the head are located the prominent *eyes*, the *antennæ*, and *proboscis*, with its pair of *palpi*. Note the relative length of the palpi with reference to the proboscis.

B. a. *Examine* the wings and body for *scales*, a feature characteristic of the mosquitoes.

b. *Examine* the *tarsal claws*, noting whether they are double or single toothed or not toothed.

Draw a number of head scales, and the tarsal claws.

C. *Sexual differences*.

a. *Examine* the *antennæ* of a male and of a female specimen, and note the plumose condition in the former sex.

D. *Characteristics* of the *Anopheles*, or malaria mosquito, as compared with the *Culex*, or rain-barrel mosquito.

a. Is there any difference in *size?*

b. Compare the *palpi*, note the extreme length in Anopheles, nearly as long as the proboscis, while in Culex they are less than half as long.

c. *Examine* the *wings* for markings, spots, etc. Note that Anopheles has spotted wings, which is the case in only a very few species of Culex.

Draw the head and its appendages in Anopheles.

E. *Compare* the *larvæ* (wrigglers) of Anopheles and Culex.

a. Note the long prominent breathing tube or *anal siphon* of Culex, short in Anopheles.

b. Note the arrangement of the tufts of hairs on the thorax and abdomen. The *anal tuft* is especially prominent.

c. *Count* the number of body segments comprising the abdominal region.

d. Examine the *palmate hairs* situated dorsally on abdominal segments.

e. On the head note the presence of *eyes*, *antennæ* and *mouth brushes*.

Draw the larvæ of both species, and *label* parts.

F. Compare the *pupæ* (tumblers) of Anopheles and Culex.

a. Examine the prominent breathing *trumpets* (air siphons) situated laterally and dorsally on the thorax. Compare the breathing trumpets as to shape and position.

Draw an Anopheles tumbler.

G. Examine a slide of mosquito eggs.

Draw several specimens.

H. a. *Examine* specimens of the yellow fever mosquito (*Stegomyia calopus*) and note the prominent silvery markings. How are these markings distributed?

b. What is the length of the *palpi* as compared with the *proboscis*? Note other characteristics.

Draw a dorsal view of the insect.

EXERCISE 10a

Buffalo Gnats

ORDER DIPTERA, FAMILY SIMULIIDÆ

A. The buffalo gnats or black flies are widely distributed; all species are small, the largest less than ¼ inch in length. Any of the common species of Simulium will serve for this study. Specimens mounted in balsam are needed for microscopic study.

a. Note the humped condition of the *thorax*, giving the insect a buffalo-like appearance.

b. The *antennæ* are short and stalky, but Nematoceron in character.

c. Notice the characteristic venation of the rather large broad *wings*. The first three longitudinal wing veins are very much stronger than the rest.

d. Examine the *mouthparts* carefully. To what subtype to the mouthparts belong?

Draw the specimen in outline.

B. If larvæ of the buffalo gnats are available examine specimens carefully and determine their adaptation to an aquatic habitat.

Draw a specimen.

EXERCISE 10b

The Horseflies

ORDER DIPTERA, FAMILY TABANIDÆ

Anatomical Study.

With a specimen of *Tabanus stygius*, *Tabanus punctifer* or other allied species before you, note the following characteristics, and *make drawings* of the parts.

a. *Antennæ*,—three-jointed, terminal segment annulated, and not possessing the arista of the housefly and its allies.

b. Last tarsal segment, note the *claws*, *pulvilli* and *empodium* between.

c. *Head*, note the large compound *eyes*, separated in the female and contiguous in the male; note the sexual difference in size of mouthparts.

EXERCISE 10c

The Horseflies

Systematic Study.

Family Tabanidæ, antennæ porrect, without arista, medium sized to large flies.

1. Genus Tabanus,—hind tibiæ without spurs, third segment of the antennæ with a well developed basal process, examples, *T. stygius*, the black and white horsefly; *T. punctifer; T. atratus*, the black horsefly; *T. costalis*, the greenhead; and *T. lineola*, the lined horsefly.

2. Genus Chrysops,—(Earflies or Deerflies)—hind tibiæ with spurs at tip, third segment of the antennæ composed of five annuli; second segment of the antennæ but little shorter than the first; wings with a dark picture; examples, *C. niger* and *C. bruneus*.

Draw one example each of the two genera mentioned above.

EXERCISE 11

The Housefly (Musca Domestica) and the Stablefly (Stomoxys Calcitrans)

ORDER DIPTERA, FAMILY MUSCIDÆ

A Comparative Study.

It will be remembered that while these two species of flies

belong to the same family of insects (Muscidæ), they differ nevertheless greatly in their powers of disease transmission, the former relating to indirect infection and the latter to direct infection.

With a specimen of each species of fly before you, note the distinguishing features, indicating the same by means of separate *drawings* of the parts, and by description in your notebooks.

a. *Mouthparts;* note the characteristic position of these organs at rest.

b. *Wing venation; draw* the right wing of each species, carefully drawing in the wing veins. Note the differences in venation by crossing (x) the parts that vary, both cells and veins.

c. *Coloration;* indicate any differences in color, or color markings, that you may observe.

d. Note any other differences in position of the wings, relative length of body, size, etc.

e. *Sexual differences;* ask your instructor for specimens of the housefly representing the two sexes. Note that in the female the compound eyes are widely separated, whereas in the male the dorsal borders come close together. In the female the terminal segments are protrusible, which should be demonstrated by pinching the abdomen with the finger or forceps. The protrusible segments make up the ovipositor.

f. Study a life history preparation of both the housefly and the stablefly, showing the egg, larva and pupa. Compare especially the posterior spiracles of the larva, and pupa with references to position, form and size. (Draw.)

EXERCISE 12

The Stablefly (Stomoxys Calcitrans) and the Hornfly or Texas Fly (Hæmatobia Serrata)

ORDER DIPTERA, FAMILY MUSCIDÆ

A Comparative Study.

With specimens of each species of fly before you, note the distinguishing characteristics, indicating the same by means of separate drawings of the parts and by description in your notebook.

These two species of flies belong to the blood-sucking branch of the Family Muscidæ, to which also belongs the genus Glossina (Tsétsé flies).

a. *Mouthparts.* The palpi of Stomoxys are relatively short, while those of Hæmatobia are long and flattened. The proboscis of the latter is also relatively more plump and is not so well thrown forward, when at rest, as in the Stomoxys, due in the latter to a well developed joint at its base.

b. *Wings.* Note the close similarity in wing venation. The wings of the stablefly are thrown wide apart when at rest.

c. *Size.* With at least half a dozen specimens of each species before you note the relative size of the individuals. *Measure* the length of these specimens in terms of millimeters.

d. *Make* a large *drawing* of the head of the hornfly, side view, to show the following parts, *compound eye*, *antenna*, and *proboscis* with *palpi.*

e. *Draw* the egg of the hornfly; note the brownish color. Enlarge sufficiently to indicate general characteristics.

f. Note differences in the sexes as indicated by the segments of the abdomen.

EXERCISE 13

FLESH-FLIES

ORDER DIPTERA, FAMILY SARCOPHAGIDÆ

mily Sarcophagidæ—thorax and abdomen provided with ristles. (Do not confuse with the Tachinidæ.)

The Texas screw worm fly, *Chrysomyia* (*Lucilia*) *macellaria.*

a. *Coloration;* general color of the body is metallic green; the thorax bears three longitudinal black dorsal stripes. The head is distinctly reddish brown in color.

b. *Size;* the size of all species of flesh flies may vary considerably within each group, due largely to lack of food during the larval period. (See Herms, "An Ecological and Experimental Study of Sarcophagidæ," 1906.) However the screw worm fly is a medium-sized fly, never attaining the size of the larger species of flies, such as the blowfly, *Calliphora vomitoria,* for example.

c. *Mouthparts;* compare with mouthparts of housefly.

d. *Wing venation;* compare with venation of housefly.

e. Note the scissors-like folding of the wings. *Draw* the specimen, indicating the striping and the characteristic folding of the wings, in particular.

B. *Examine* and *draw* a specimen of the bluebottle fly, *Calliphora vomitoria.* What are its characteristics?

C. *Examine* and *draw* a specimen of the greenbottle fly, *Lucilia cæsar.* How does this species differ from Chrysomyia?

D. *Study* and *draw* mounted specimens of flesh fly larvæ, noting the *oral hooks,* or mandibles, *shape, color* and *posterior spiracles.*

EXERCISE 14

The Bot and Warble Flies

ORDER DIPTERA, FAMILY ŒSTRIDÆ

A. With two specimens of Œstridæ before you, one *Gastrophilus equi*, the horse bot, and one *Hypoderma lineata*, the ox warble fly, study the following characters, noting that the examples are rather thickset and covered with hair, and that the mouthparts are vestigial, the eyes small and bare, the squamæ large.

a. *Antennæ* are small, three-jointed and decumbent, as in the Muscidæ. In the horse bot the *arista* is bare, while in the warble fly it is plumose.

b. *Tarsi* of front legs, broad, flattened and hairy in Hypoderma, while they are slender and less hairy in Gastrophilus.

c. *Wing venation;* note the difference between the genera.

d. *Sexual characters;* notice the difference between the sexes in the terminal abdominal segments.

Draw the characteristic details.

B. *Larval Characters.*

a. *Segmentation; count* the segments, paying especial attention to the terminal ones.

b. *Hooklets;* in the horse bot note the presence of a pair of outer hooklets used for attachment to the walls of the stomach. Note also a pair of inner straight points (not hooked). Are these anterior or posterior?

c. *Tubercles;* in the warble notice the dorsal spindle-shaped tubercles on the median segments and their arrangement.

d. Examine a specimen of the head maggot of sheep (*Œstrus ovis*).

Draw a specimen of each.

EXERCISE 15a

The Fleas

ORDER SIPHONAPTERA

Anatomical Study.

In order to find the following characters two species of fleas should be used, namely, the human flea (*Pulex irritans*), and the dog flea (*Ctenocephalus canis*). Note the entire absence of wings and the characteristic laterally compressed condition of the body ,with legs strongly developed for springing.

a. *Legs;* observe the greatly elongated *coxæ*, and other segments.

b. *Mouthparts;* composed of sharp piercing structures; a detailed study of which may be omitted here.

c. *Antennæ;* short, three-segmented, usually sunken in a pit. The terminal segment is swollen and annulated.

d. *Combs;* rows of spines on the head (oral), and thorax (pronotal), forming combs (ctenidia) are used to separate the fleas of the family Pulicidæ into the combed and non-combed species. The number of spines in each comb is also useful for classification. In the dog flea notice the two rows of combs and count the number of spines in each.

e. *Eyes*, which may be present or absent, are of a simple type.

f. Examine and draw a specimen of flea larva.

g. Examine and draw specimens of flea eggs.

Draw one example of each species of flea.

EXERCISE 15b

The Fleas

ORDER SIPHONAPTERA

Systematic Study.

Order Siphonaptera—wingless insects, laterally compressed, body highly chitinized, provided with many regularly arranged spine-like hairs.

A. Family Sarcopsyllidæ, "Small fleas with disproportionately large heads; female a stationary parasite with worm-like or spherical abdomen, burrowing into the flesh of the host; labial palpi one-segmented; no 'combs' of spines on head, thorax or abdomen" (Kellogg).

a. Examples, *Sarcopsylla penetrans*, the jigger-flea or chigoe of mammals, including man.

b. *Xestopsylla gallinæ*, the hen flea.

B. Family Pulicidæ, "larger fleas with proportionately small head; adults active temporary parasites, with abdomen always compressed; labial palpi 3 to 5 segmented; head, thorax or abdomen often with 'combs' of spines" (Kellogg).

a. Examples, *Pulex irritans*, the human flea, non-combed.

b. *Ctenocephalus canis*, the dog and cat flea, two sets of combs, one oral and one thoracic.

c. *Ceratophyllus fasciatus*, the rat flea, thoracic comb present, but oral comb absent.

d. *Ceratophyllus acutus*, the squirrel flea, thoracic comb present, consisting of nine spines on one side.

Draw the hen flea and either the rat flea or the squirrel flea.

EXERCISE 16

Louse Flies

ORDER DIPTERA, FAMILY HIPPOBOSCIDÆ

A. The louse flies are extremely chitinous, dorso-ventrally flattened insects, with suctorial mouthparts. Most of the species are winged, and are often also called forest flies; the wingless species are called "ticks," but should not be confused with the true ticks (Ixodidæ).

B. Study a specimen of the sheep "tick," *Melophagus ovinus*, noting the following characteristics:

a. Louse-like *form* and reddish *color*.

b. The *head* is extremely small and the *proboscis* is prominent.

c. The species is *wingless*.

Draw the specimen.

C. *Examine* a *puparium* of *Melophagus ovinus*.

D. If available, *compare* a deer "tick," *Lipoptena depressa* with the above.

E. The forest fly, *Hippobosca equina*, is a *winged* species.

a. In what respects does this species differ from *Melophagus ovinus?* In what respects do the two agree?

Draw the specimen.

EXERCISE 17a

The Ticks

ORDER ARACHNIDA, FAMILY IXODIDÆ

Anatomical Study.

Ticks belong to the same group as do the spiders, and therefore have four pairs of legs in the adult stage. With a specimen of the

wood tick (*Dermacentor variabilis*) or the Texas fever tick (*Margaropus annulatus*), before you, *study* and *draw* the following characters, making one drawing of the whole animal and separate drawings necessary to show the details.

a. *Rostrum*, consisting of the head and mouthparts.

b. *Labium* or *hypostome*, a continuation forward of the head (snout-like) possessing longitudinal rows of teeth.

c. *Mandibles* or *cheliceres*, one pair, terminating in well defined teeth. The cheliceres work, each in a separate sheath.

d. *Palpi* or *pedipalpi*, segmented structures varying considerably in relative length in the various genera.

e. The eight *legs* are composed of the following parts: *coxa*, *trochanter*, *femur*, *tibia*, *protarsus*, *tarsus*, *ungues* (claws) and *pulvillus* (absent in Argasinæ).

f. *Scutum* or *shield*, a chitinous plate covering a portion of the dorsal part of the body back of the head. This shield is often ornamented with spots, furrows and perforations.

g. *Eyes*, present in Dermacentor and a few other genera, but absent in a number of other genera, including Margaropus.

h. *Anus*, ventrally located, removed from the posterior border and guarded by *anal plates*.

i. *Anal groove*, a furrow either posterior or anterior to the anus, depending on the genus, and useful in classification.

j. *Spiracles* with *guard plates*,—situated laterally and ventrally, in some species in front of the fourth coxæ, or in some behind the fourth coxæ.

k. *Marginal festoons;* the marginal border of the abdomen is often crenellated.

l. *Sexual differences;* the shield or scutum of the male covers the greater part of the dorsum, while in the female it extends over only a small portion posterior to the head. The male is usually considerably the smaller and more slender, and is louse-like in appearance. Though this is true for the Ixodinæ, to which group the specimens studied belong, in the Argasinæ the sexes are more difficult to distinguish.

EXERCISE 17b

The Ticks

ORDER ARACHNIDA, FAMILY IXODIDÆ

Systematic Study.

Family Ixodidæ.

A. Subfamily Ixodinæ, scutum present, pulvilli present, mouthparts projecting in front.

a. Examples: *Margaropus annulatus*, Texas fever tick or blue tick, scutum uniformly chestnut brown in color, labium or hypostome with eight rows of teeth. Front pair of legs emerging from the shoulders. What is the form of the guard plates of the spiracles?

b. *Dermacentor variabilis*, American dog tick, scutum spotted with silver. Front pair of legs emerging close to capitulum. What is the form of the guard plates of the spiracles?

B. Subfamily Argasinæ, scutum absent, pulvilli absent, mouthparts hidden under body.

a. Examples: *Argas miniatus*, American poultry tick, body flat with thin edges, body oval, with rectangular marginal festoons.

b. *Ornithodorus megnini*, the spinous ear tick, body lyre-shaped and covered with spines.

Draw from specimens, using hand lens or binocular microscope the three species not previously drawn.

EXERCISE 18a

Other Ticks

As far as it is possible to secure material *examine* specimens of the following species of ticks, *taking notes* and *making drawings*

of the same to fix the general characteristics of each in your mind.

A. Ixodinæ.

a. *Amblyomma americanum* is the Lone Star tick. Notice the bright silvery spot at the posterior end of the scutum.

b. *Dermacentor venustus* is the Rocky Mountain spotted fever tick. Notice the large size of the scutum, which has a dark lyre-shaped figure upon it on a silvery background.

c. *Rhipicephalus sanguineus* is the brown dog tick.

d. *Ixodes scapularis* is the black legged tick or American castor bean tick; the scutum is chestnut colored as in the Texas fever tick, but the body has the shape of a castor bean, the legs are black, and emerge from the body quite close to the mouth-parts.

e. *Rhipicephalus appendiculatus* is one of the ticks responsible for the transmission of African coast fever of cattle.

B. Argasinæ.

a. *Ornithodorus moubata* is responsible for the transmission of African relapsing fever of man.

b. *Argas persicus* is the Persian poultry tick, to which *Argas miniatus* is very closely related. These ticks are responsible for the transmission of Fowl Spirochætosis.

EXERCISE 18b

Life History Study of the Ticks

A. *Examine* a prepared slide of tick eggs.

B. If available, *examine* an ovulating female tick. Notice that the mass of eggs lies anterior to the body, with the head buried in it. Why?

C. *Examine* mounted specimens of ticks that have recently emerged from eggs, noting particularly the number of legs.

D. *Compare* specimens of young female ticks with specimens that are fully engorged.

E. *Examine* again a series of males and females of several species, to determine sexual differences.

EXERCISE 19a

The Mites

CLASS ARACHNIDA, ORDER ACARINA, FAMILY GAMASIDÆ

A. *General characteristics of mites;* usually quite small, just about visible to the naked eye, some larger. The body portions are more or less closely united. The mouthparts are piercing and sucking structures. The four pairs of legs are generally well developed, terminating in suckers. The sexes are separate. The young are hexapod.

B. *Characteristics of Gamasidæ;* the legs are six-segmented and terminate in a pair of ungues and a sucker-like disc. The stigmata or breathing pores are located between the third and fourth pairs of legs.

C. The poultry mite, *Dermannyssus gallinæ.* Study specimens mounted in balsam.

a. *Measure size* of the specimens. How do the males and females differ in this respect?

b. Note the position of the *legs* with respect to the body divisions.

c. *Count* the segments of a leg and note the terminal structures.

d. *Locate* the *stigmata.*

Draw the specimen, *labelling* the parts.

EXERCISE 19b

The Mites

CLASS ARACHNIDA, ORDER ACARINA, FAMILY SARCOPTIDÆ

A. *Characteristics of Sarcoptidæ.* The legs are six-segmented, short and thick, and terminate in a sucker or a slender bristle ending in a disc-like sucker.

B. *Sarcoptes scabei var. suis.* This variety of itch mite inhabits the skin of the domestic pig, tunneling its way through the epidermis, causing a scaly appearance. This variety may also attack man.

a. Note the minute *size* of this species. How does it compare with the poultry mite in this respect?

b. How does it compare in *color* with the poultry mite?

c. What is the *form* of the body and position of legs?

d. Note the transverse rows of *bristles* on the dorsal surface of the mite.

e. Study the terminal structures of the leg, noting especially the spines and sucker (ambulacrum).

Draw the specimen.

EXERCISE 20

Other Mites

CLASS ARACHNIDA, ORDER ACARINA, FAMILY SARCOPTIDÆ (cont.)

A. *Psoroptes communis var. ovis* is the scab mite of sheep, producing scabies. Comparing this Psoroptic mite with the Sarcoptic mites, notice the following characteristics:

a. The *body* is elongate oval.

b. All four pairs of *legs* appear beyond the margin of the body.

c. The third pair of *legs* is devoid of *ambulatory suckers*, and in their place note a long pair of bristles for each leg.

Draw a female specimen.

B. *Psoroptes communis var. bovis* is the mange mite of the ox.

a. Can you find any perceptible difference between this species and the one above?

C. *Psoroptes communis var. equi* is the mite which causes humid mange of the horse.

a. The rostrum is characteristically long, twice as long as broad, otherwise the species differs but imperceptibly from the species above.

D. *Sarcoptes scabiei var. canis* is one of the mange mites of the dog.

a. Notice similarity to the variety inhabiting swine.

E. *Sarcoptes mutans* is the parasite which causes scaly leg in poultry.

Examine a bit of mounted scrapings from the leg of a hen affected with scaly leg. The circular mites (typically Sarcoptic) are easily visible.

Draw the specimen.

EXERCISE 21a

The Insect Sting

The insect sting, as found in the Hymenoptera (bees, wasps and ants) is a modified ovipositor, the function having been changed from that of an egg apparatus to that of a defensive weapon. In many insects the sting still serves both purposes.

A fresh worker bee should be used for study; these can usually be procured at a nearby apiary, or bees may be killed in the field just before using.

With a needle remove the last evident scale-like segment of the abdomen, which will bring with it the sting, the venom sac

and much of the alimentary canal. The sting can be recognized at once as a fine needle-like structure, and the venom sac as a very small semi-transparent sac. With needles carefully separate the sting with the sac and other accessory structures. Teasing out these structures can well be accomplished under water, with the aid of a dissecting microscope or binocular. The following parts should be noted, *drawn* and *labelled:*

a. The *sting* proper, consisting of two darts, ending in distinct serrations and bending at the base to either side for muscular attachment and leverage.

b. The *sheath,* partly enclosing the upper part of the darts, and terminating in a fine cutting edge at the distal edge of the sting proper. It also serves to direct the flow of venom into the wound.

c. The *sting palpi,* situated on either side of the darts.

d. The *venom sac,* emptying by means of a broad neck into the poison channel.

e. The *poison gland,* recognizable as a long coiled tube leading into the anterior end of the venom sac.

EXERCISE 21b

Venomous Spiders and Scorpions

CLASS ARACHNIDA, ORDER ARANEIDA AND ORDER SCORPIONIDA

A. The most venomous of our few dangerous spiders is *Lactrodectes mactans.* With a specimen of this spider before you, note the following characteristics:

a. It is a *medium-sized* spider.

b. The *color* is brownish black to inky black.

c. Notice two brick red triangular *spots* on ventral side of abdomen.

d. Notice the comparative absence of *hairs* on the body of this species.

e. Notice the *mouthparts*. How does the spider "bite"?

Draw the specimen.

B. Our commoner scorpions are represented by the three genera,—Centrurus, Hadrurus, and Uroctonus.

Examine a specimen for the following characteristics:

a. What is the form of the *mouthparts?*

b. What is the form and function of the *chelicerœ?*

c. How many *walking appendages* has the scorpion?

d. *Examine* the *sting* at the tip of the abdominal appendage.

Draw the specimen.

C. *Examine* specimens of the whip scorpion (Order Pedipalpi).

EXERCISE 22

PARASITICIDES

Poisons and repellents. The student should familiarize himself with at least a few of the commoner materials used to destroy or repel parasites of man and the domesticated animals. Samples of each of the following materials should be *examined*, and *notes* should be taken describing the physical properties, such as color, smell, weight, whether liquid or solid, whether homogeneous or a mixture, etc. *Caution!* Do not *taste* these materials; they are *Poisons*.

a. *Nicotine* (tobacco decoction) is used as a dip for the destruction of scab mites on sheep and also against lice and mites on other animals which do not vomit. Nicotine is a poison. The proportion of tobacco decoction used depends on the nicotine content. "Black leaf 40," a commercial brand, has a high nicotine content. One pound of a forty per cent solution of nicotine to 100 gallons of water (soft water) would make a dip answering the requirements of the U. S. Bureau of Animal

Industry as used against sheep scab, but the addition of sulphur (16 pounds to the above formula) is recommended.

Examine a sample of tobacco decoction.

b. *Lime* and *sulphur* form the active ingredients for a dip used against scab mites of both sheep and cattle. When used for scab in sheep the following formula is recommended: 24 lbs. flowers of sulphur, 8 lbs. of unslaked lime to 100 gallons of soft water; when used for cattle scab or mange, the lime should be increased to 12 lbs.

Examine a sample of lime sulphur solution.

c. *Cresol* is a coal tar product of high cresylic acid content (from 90% to 98%) and is ordinarily a straw-colored liquid. Cresol is poisonous, and corrosive. In order to produce a mechanical mixture with water, cresol is carefully mixed with linseed oil or soap, and when prepared according to the U. S. Pharmacopeia is known as "liquor cresolis compositus." As a disinfectant, it is useful diluted with water at from 2 to 4%. It is also used as an ingredient in sheep dip. The percentage of cresol used with water depends on the government rating of the cresol.

Examine a sample of cresol, and of liquor cresolis compositus.

d. *Crude Carbolic Acid* is a coal tar product with a low phenol and cresylic acid content. It is poisonous. (Pure carbolic acid—phenol—must not be confused herewith.) In using carbolic acid as an ingredient for dips and disinfectants, the phenol content should be known, since there is considerable fluctuation in the amount of this ingredient. Dilution with water to 2 to 4% of its phenol content is sufficient for disinfection. For dipping the same may be said as for cresol.

Examine a sample of crude carbolic acid, and samples of carbolic acid crystals, which are pure phenol.

e. *Creoline* is a coal tar product of a low phenol content. It is poisonous. Creoline is much used for dipping and disinfection. Drop a little in water and notice the result. For dipping purposes dilute with water to from 2 to 4%. It is useful in destroying lice, and less so for scab mites, on domesticated animals.

For human head lice, creoline (2%) may be applied by means of a fine tooth comb.

f. *Kerosene* is an extremely useful insecticide, but must be diluted to prevent injury to animals, and is therefore preferable as a spray for coops and stalls infected with mites or lice. Kerosene may be used pure for the latter purpose, or as an *emulsion* not weaker than 1 to 10. The emulsion is prepared by dissolving ½ lb. of soap in one gallon of hot water and adding one gallon of kerosene. This forms a stock solution, and illustrates the proportion for all practical purposes.

Examine a sample of kerosene emulsion, both in stock and diluted one to ten.

g. *Arsenic* may be used as the active ingredient for sheep dips and cattle dips. It is extremely poisonous, and the heads of animals dipped must be kept out of the solution and the cattle prevented from licking themselves or each other. Persons employed in dipping operations must proceed with caution. Dipping vats and stock solutions must be kept tightly closed to prevent animals from drinking the poison. Dripping animals must not be permitted where there is green herbage.

Examine a sample of arsenic crystals.

h. *Pyrethrum powder*, or buhac, is a fine yellow dust made from the flower of *Chrysanthemum cinerariafolium*. This powder is useful against lice and fleas. It is applied by means of an insufflator or duster, and must be freely used.

Examine a sample of pyrethrum powder or buhac.

i. *Naphthalene flakes* are very useful as a repellent. The flakes are dusted on the animals, and brushed into the hair freely. Lice and fleas are strongly repelled.

Examine a sample of naphthalene flakes.

j. *Tobacco dust* or snuff, added in equal parts or one to three of road dust is extremely useful as a dust bath for poultry. Some sulphur may well be added.

Examine a sample of tobacco dust.

k. *Sulphur* may be used in cones, with wicks, for fumigating

purposes, or as flowers of sulphur, to be mixed with tobacco dust, as above, or in the form of an *ointment*, against scab and mange mites on domesticated animals, or for human scabies (itch). An effective sulphur ointment is prepared as follows:

Sulphur, 1 oz., carbonate of potash ½ oz. and lard 4 oz.

Examine some flowers of sulphur and a sulphur cone.

l. *Formaldehyde* is a splendid disinfectant and a good stomach poison for flies, but is useless as a spray against insects. As a fly poison formaldehyde purchased in about 38% to 40% solution must be diluted with water to about 2% or even less, that is, one part to twenty or thirty parts of water. This must be made accessible to the flies in shallow vessels.

Examine some formaldehyde.

m. *Oil of Citronella* is a good repellent against mosquitoes, black gnats, etc. It should be applied full strength to the hands and face.

Examine a sample of oil of Citronella.

m. *Larkspur* (*Delphinium staphisagria*) is useful in the destruction of both the human head louse and the crab louse. It is ordinarily used in the form of tincture or ointment (Unguentum Staphisagria) 10%.

Examine a sample of tincture of larkspur.

EXERCISE 23a

The Amœbæ

PHYLUM PROTOZOA, CLASS RHIZOPODA (SARCODINA), ORDER AMŒBÆA

A. In prepared specimens on slide of *Entamœba histolytica*, the amœba of Oriental dysentery, note the following: (The student is cautioned against confusing these with leucocytes and foreign matter.)

a. Outer clear portion, the *ectosarc.*

b. Inner granulated portion, the *entosarc.*

c. The irregular projections, the *pseudopodia,* in which the ectosarc is best seen. These are organs of locomotion.

d. In the entosarc a dark globular body is visible, the *nucleus.*

e. Some specimens may show one or more clear globular bodies in the entosarc, the *vacuoles.*

Draw several specimens.

B. *Examine* the slide for *encysted* amœbæ.

EXERCISE 23b

The Trypanosomes

PHYLUM PROTOZOA, CLASS FLAGELLATA (MASTIGOPHORA), ORDER LISSOFLAGELLATA

A. In prepared samples of blood smears from an animal affected with Nagana, note the presence of spindle-shaped organisms with a whip-like appendage, *Trypanosoma brucei,* the trypanosome of Nagana.

a. A single whip-like appendage, the *flagellum.*

b. A thin fold along the dorsal edge, the *undulating membrane.*

c. Near the middle of the body a dark object, the *nucleus.*

d. Near the anterior end (the flagellum end) of the body, a small mass of chromatin, the *blepharoplast.*

Draw several specimens.

B. In a suitable blood smear from a rat, *examine* for trypanosomes, in this case *Trypanosoma lewisi.*

Compare A and B.

C. In a blood smear taken from a patient suffering from African sleeping sickness, first stage, *examine* for *Trypanosoma gambiense.*

Compare this with A and B.

D. *Examine* a specimen of Tsétsé fly, the carrier of A and C.

a. *Examine* the *mouthparts*.

b. Examine the *antennæ* with plumose arista.

c. Note general *form* of the fly, constricted "waist."

Draw the specimen in outline.

E. As a matter of comparison, in a suitable preparation from a fowl suffering with Spirochætosis, study and *draw* the causative organism, *Spirochæta gallinarum*, and compare this further with *Treponema pallida* of Syphillis.

EXERCISE 24

The Malaria Parasites

PHYLUM PROTOZOA, CLASS SPOROZOA, ORDER HÆMOSPORIDIA

Note:—It is expected that the student will read some concise account of the normal constituents of the blood before proceeding with this exercise, e. g. at least the first 9 pages of Chapter I, "Practical Study of Malaria," by Stephens and Christophers.

A. Sporozoan of quartan malaria, *Plasmodium malariæ*.

For this exercise use stained blood films from malarial patients.

Examine slides from cases of quartan infection (malaria with fever recurring every three days, 72 hours). Look for pigmented bodies inside of red corpuscles. Determine the following stages:

a. Small round pigmented body shortly after having entered the corpuscle.

b. *Signet rings*, young intracorpuscular parasites.

c. The parasite nearly filling the corpuscle, showing as a deeply pigmented body consisting of coarse granules. A number of darker bodies may be seen in the parasite, indicating the presence of the *nucleoli* preparatory to sporulation.

d. Find a corpuscle showing the parasite in a segmented con-

dition, each spherical element provided with a nucleolus and the eight or ten elements arranged so as to give the appearance of a daisy.

e. Find a corpuscle that has been broken down, thus liberating the sporulated parasite.

Draw several stages.

B. Sporozoan of benign tertian malaria, *Plasmodium vivax.*

Examine blood slides from cases of tertian infection (malaria with fever recurring every two days, 48 hours).

a. Note the fact that the pigmented granules of this parasite are considerably finer than in the quartan.

b. *Signet rings* as in A.

c. In the segmentation stage of this form note the irregularity in arrangement of the elements and their greater number.

Draw several stages.

C. Sporozoan of malignant tertian fever, *Plasmodium præcox.*

In a slide taken from an advanced case of malignant tertian malaria (æstivo-autumnal fever) note the presence of:

a. Crescent-shaped bodies either free or intracorpuscular (usually only one in a red corpuscle). The crescent stage in this variety of parasite represents a condition just previous to the sexual changes undergone in the body of the Anopheles mosquito, or on contact with the air (see below). Female crescents have the chromatin massed centrally while the male crescents have it distributed and are hyaline.

b. The parasite of malignant tertian malaria (*Plasmodium præcox*) is said to be smaller in the mature form than is the benign tertian parasite.

c. Examine signet rings for double nuclei.

Draw crescents.

D. The stained parasites of malaria often show ring forms, and when stained with Romanowsky stain, the red nucleus may be between the ends of the slender crescent, forming thus a "*signet ring.*"

a. *Examine* slides for the "signet ring" forms.

E. Outside of the corpuscles in the preparations already examined *search* for flagellated bodies, the *microgametes* (spermatozoans), or male sexual elements. These are produced from crescent-containing blood on exposure to air for a few minutes. (Some species do not form crescents before flagellation, e. g. the benign tertian and the quartan.)

F. In a stained preparation of the salivary glands of a malaria-infested Anopheles mosquito determine the presence of *sporozoits*, recognizable as slender, slightly curved rods.

G. In a stained preparation of the midgut of a malaria-infested Anopheles mosquito, determine the presence of *sporoblasts*, as pigmented bodies (elongate, as sporozoits when advanced) inside of *cysts* recognizable as wart-like bodies external to the gut.

H. As a matter of comparison examine a blood smear of Texas cattle fever, and study and draw the causative organism *Babesia* (*Piroplasma*) *bigeminum* with reference to form and relative size. This organism is carried by the cattle tick, *Margaropus annulatus*.

PART II

HELMINTHOLOGY

INTRODUCTION

The object of the following exercises is to acquaint the student with the commoner parasitic *worms* infesting man and the domesticated animals.

Formerly the term *Vermes* was used to cover all groups of worms. This group is now divided into a number of *phyla*, of which the following include parasitic forms:

a. *Nemathelminthes*. Commonly called thread worms, or roundworms, they are cylindrical, non-segmented animals, usually more or less tapering at both ends. The alimentary canal is simple and well developed, except in the Acanthocephala. The water-vascular canals are usually conspicuously located on both sides, longitudinally. The sexes are separate and development is usually direct, i. e. without a necessary intermediary host. Examples are the roundworm of the horse, (*Ascaris megalocephala*), and the trichina of swine, rats and man, (*Trichinella spiralis*).

b. *Annelida*. Worms composed of a series of rings, this segmentation often affecting the internal organs. The number of segments is usually large, a fact that will differentiate these worms from certain parasitic insect larvæ, in which the segments are generally 11 or 12, never more than 19 or 20. Internally, of course, the presence of a tracheal respiratory system will differentiate the latter. Examples are the common earthworm (*Lumbricus terrestris*) and the medicinal leech (*Hirudo medicinalis*). (The latter only need be considered here.)

c. *Platyhelminthes.* In this group of worms the body is more or less flattened dorso-ventrally. The digestive tract may be entirely lost, as in the tapeworms, or may consist of a blind sac, more or less branched, as in the flukes. An anal aperture is never present. The flat-worms are usually hermaphroditic, and development in the parasitic species is usually indirect, i. e. through an intermediary host. Examples are the pork tapeworm of man (*Tænia solium*) and the liver fluke of sheep [*Fasciola* (*Distoma*) *hepatica*].

To distinguish worms from insect larvæ. When insect larvæ (parasitic in the body of higher animals) are encountered, there may be some difficulty in differentiating them at once from worms, because of their environmental setting. Instances of this are bots and warbles (Œstridæ), screw worms (*Chrysomyia macellaria*) and flesh fly larvæ (Sarcophagidæ) in intestinal myiasis. Usually these larvæ are short and plump, with well-marked segments, few in number, usually 11 or 12, certainly not more than 20. Furthermore, microscopic examination will reveal a system of tubules in the insect, extending internally to all parts of the body, the tracheal breathing system.

EXERCISE 25a

The Roundworms

PHYLUM NEMATHELMINTHES, CLASS NEMATODA, FAMILY ASCARIDÆ

The roundworm of the horse—*Ascaris megalocephala.*

A. *Characteristics of Nematoda.* The roundworms or threadworms may be recognized by their cylindrical, non-segmented or non-jointed form, covered with a rather thick cuticle, and the presence of a simple, well-developed alimentary canal; also a pair of lateral longitudinal water-vascular canals, usually

conspicuous. The mouth is terminal. The sexes are separate, and the males are generally shorter and more slender than the females. The development is usually direct (exceptions) and requires no intermediate host (exceptions).

B. *Characteristics of Ascaridæ.* The Ascaridæ are generally large-sized worms (more than 2 mm. in thickness at the middle in the typical Ascarids, much less in Oxyurids). The terminal mouth is surrounded by three prominent papillæ or lips, one situated dorsally and two ventrally. The anus is located ventrally just anterior to the termination of the body.

C. *Examine* specimens of *Ascaris megalocephala*, the roundworm of the horse. This species is chosen for use because of its convenient size and typical characteristics.

a. Note *sexual differences* in *size* and the presence of two terminal *spicules* of equal length in the male.

b. Examine the oral *papillæ* or lips, and the ventral transverse *anal aperture.* How can you locate the dorsal and ventral sides of the animal?

c. Notice the two lateral longitudinal *water-vascular canals.*

d. *Measure* the *length* of several specimens in centimeters.

Draw a specimen and *label* the parts.

e. *Examine* several posterior and median cross-sections of a female Ascaris, noting the presence of the intestine, and uterus with ova.

D. *Examine* other species of Ascaris, noting especially *size* and *color*, viz.:

a. *Ascaris lumbricoides* of man.

b. *Ascaris suilla* of swine.

c. *Ascaris vitulorum* of cattle.

d. *Ascaris mystax*, the mawworm of dogs and cats.

EXERCISE 25b

Other Ascaridæ

A. Study mounted specimens of *Oxyuris vermicularis*, the pinworm of man, noting,

a. The *length* in millimeters.

b. The *form* of the body, tapering from the middle toward the blunt anterior end, with thrice papillated mouth, and terminating posteriorly in a fine pointed tail.

c. What are the *sexual differences?*

Draw male and female specimens.

B. *Examine* specimens of *Oxyuris curvula* of the horse, and the long-tailed species of the same host, *Oxyuris mastigodes.*

C. Study mounted specimens of *Heterakis papillosa*, the cæcum worm of the hen.

a. Notice the three-lobed lips or *papillæ.*

b. What is the average *size* and *form* of this species?

c. *Examine* male specimens, locating the two posterior *spiculæ.*

Draw male and female specimens.

EXERCISE 25c

Thorn-Headed Worms

PHYLUM NEMATHELMINTHES, CLASS ACANTHOCEPHALA

The thorn-headed worm of swine,—*Echinorhyncus gigas.*

A. *Characteristics of Acanthocephala.* Ascaris-like worms, with a rostrum covered with recurved hooks; intestine absent.

B. *Echinorhynchus gigas. Examine* specimens of the thorn-headed worm of the pig for the following characters:

a. *Measure* the *length* of the specimens. How do the sexes compare in this respect?

b. *Examine* the *rostrum* and note the position of the hooklets.

c. *Examine* a cross-section of this worm.

d. How does this worm procure its food?

Draw a specimen to show general form, and *make* a detailed drawing of the rostrum, showing the hooklets.

C. *Examine* a specimen of one of the beetles which serve as intermediary host, e. g. *Melolontha vulgaris*, the European May beetle or a species of Lachnosterna.

EXERCISE 26

The Hookworms

PHYLUM NEMATHELMINTHES, CLASS NEMATODA, FAMILY STRONGYLIDÆ

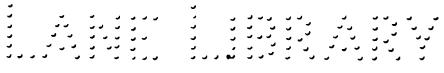
A. *Characteristics of Strongylidæ.* Nematode worms with six circumoral papillæ, with or without a buccal capsule, in either case may have an armature of teeth or hooks. Females have two ovaries, with genital pore usually posterior, but may be in front of middle; oviparous, with direct development. Caudal bursa of males is lobed, each lobe with supporting rays, and two spiculæ about equal in length.

B. *Ankylostoma duodenale* is the European hookworm of man.

a. *Measure length* of several specimens, determining first the sex.

b. Just inside the oral aperture notice the presence of recurved *teeth.* How many teeth are there in all and what is the arrangement?

c. At the base of the buccal cavity there are also present several chitinous processes.



d. Notice the long slender *spicules* of the males. Are they of equal length or not, and how many are there?

Draw male and female specimens.

C. *Necator* (*Uncinaria*) *americana* is the American hookworm of man.

a. How does it compare with the above species in *form* and *size?*

b. Is the *buccal capsule* as large as the above?

c. Compare the form and arrangement of the *teeth* with the above.

Draw a specimen, showing only the anterior end with buccal cavity and teeth.

D. *Strongylus edentatus* is the blood-sucking strongylid of the horse. Examine specimens of this or the related species, *Strongylus* (*Sclerostoma*) *armatus*.

a. *Strongylus edentatus* is called the "Toothless Strongylid." Are there no teeth in the *buccal cavity?*

b. *Examine* specimens of both males and females and compare these with human hookworms as to *size*, *form* and other characters.

Draw a specimen to show general outline.

EXERCISE 27

Other Hookworms

A. *Monodontus phlebotomus* is commonly called the hookworm of cattle, and is the probable cause of salt sickness. *Examine* mounted specimens and make the following determinations:

a. What *Strongylid characters* do these worms possess?

b. *Examine* the large *buccal capsule*, "provided at its base with a strong *dorsal tooth* projecting into its cavity, and with four *ventral teeth* or lancets." (Ransom.)

c. What is the relative *length* of males and females?

Draw a complete specimen and *make* a separate *drawing* of one showing the details of the buccal cavity.

B. *Examine* a specimen of *Monodontus trigonocephalus*, the hookworm of sheep. What are the main points of contrast with the above?

C. Study mounted specimens of *Œsophagostomum columbianum*, the cause of nodular disease of the intestine of sheep. How does this compare with the bovine-inhabiting species as to relative size of *buccal cavity?*

Draw the specimen.

D. Another common Strongylid parasitic in the intestine (fourth stomach) of sheep is *Hæmonchus contortus*, also a hookworm, but possessing a narrow buccal cavity. Notice the twisted condition of the body in the female, due to ovaries wound spirally around the intestine.

Examine and *draw* specimens of male and female.

EXERCISE 28

The Lungworms

PHYLUM NEMATHELMINTHES, CLASS NEMATODA, FAMILY STRONGYLIDÆ

A. *Dictyocaulus viviparous* (*Strongylus micrurus*) is the lungworm of cattle. The worms inhabit the bronchia and lungs of young calves, especially. Eggs are deposited in the lungs and air passages and are coughed out by the host.

a. *Examine* a portion of the lung of an infested calf in which the worms are present in "pockets." If available examine an infested lung which has been cut open. What can you say about the distribution of the worms in the lung? *Strongylosis* is the term applied to this infestation.

b. Study a mounted specimen under a low power. Note the presence of six circumoral *papillæ*.

c. In a stained female specimen note the presence of two *ovaries*.

d. In a mounted male specimen notice the presence of a pair of caudal *spicules*. Are the spicules of equal length? *Examine* the caudal membrane for *ribs*. How many ribs are there?

Draw both specimens, showing details.

C. *Examine* a slide with young and embryo Strongylids.

Draw an example of Strongylid larva.

D. Study specimens of *Strongylus ovis pulmonis*, the lungworm of the sheep. Describe the specimen and determine main points of difference as compared with the above species.

E. Study specimens of *Syngamus trachealis*, the gapeworm of chicks.

Draw a specimen.

EXERCISE 29a

The Whipworms

PHYLUM NEMATHELMINTHES, CLASS NEMATODA, FAMILY TRICHOTRACHELLIDÆ

A. *Characteristics of Trichotrachellidæ.* "Recognizable by the œsophagus, which resembles a necklet of pearls; the anterior part of the body is usually of thread-like slenderness, the posterior part of the body, which contains the genitalia, is more or less thickened; there may be no spicules or only one. There is a single ovary; vulva situated at the border line between the anterior and posterior parts of the body." (Braun.) In the subfamily Trichurinæ there is a single spicule in the male; development is direct, without encysted larval stage; and eggs pass out of the body of the host and do not hatch until taken

into the body again. In the genus Trichuris, the typical whipworm, the anterior portion of the body is of thread-like slenderness and longer than the posterior heavy portion of the body.

B. There are several species of whipworms belonging to the genus Trichuris, all of which partake of the characters above mentioned.

Examine and *draw* specimens of the following species.

a. *Trichuris* (*Trichocephalus*) *trichuris* is a common whipworm of humans. Note the following characters; position of *mouth*, length of thread-like œsophageal region as compared with the thick body; total *length*, *color*. In a male specimen find the *spicules*.

b. *Trichuris ovis* is a common whipworm of sheep, cattle and goats.

EXERCISE 29b

TRICHINA

PHYLUM NEMATHELMINTHES, CLASS NEMATODA, FAMILY TRICHOTRACHELLIDÆ

Trichinella spiralis is the cause of trichinosis of humans and other mammals. The adult trichinæ inhabit the large and small intestines of several species of mammals, among them man, the domestic pig and the rat. The worms find their way into the intestine with infested flesh eaten by one of the animals mentioned. In the intestine copulation takes place between male and female trichinæ; the female gives birth to living young in great numbers; these are carried by the lymph and blood to many parts of the body, finally finding lodgment in the muscles, where they invade the connective tissue and even the fibres, later becoming encysted.

a. *Examine* under a compound microscope a prepared piece

of diaphragm of the rat or pig infested with *Trichinella spiralis*. *Count* the *number* of cysts for a given area, e. g. 1 sq. cm.

b. *Examine* the specimen with the naked eye. Can you see the cysts?

c. Is there any general *position* that the trichina has taken within the cyst?

d. Find trichinæ that show advanced stages of *calcification*.

e. *Examine* the adjacent muscle fibres to determine effect on the same.

Draw a characteristic specimen of trichina, showing it in its relation to the muscle.

EXERCISE 30a

The Filariæ

PHYLUM NEMATHELMINTHES, CLASS NEMATODA, FAMILY FILARIIDÆ

A. *Characteristics of Filariidæ.* "Body long, filiform; mouth surrounded with papillæ, or provided with two lips; œsophagus slender, without posterior bulb. Males with single spicule or two unequal spicules. Females with two ovaries, vulva usually in front of middle of body. Usually oviparous. Development in many cases requires an intermediate host." (Ransom.) The Filariæ are extremely slender hair-like worms inhabiting the blood and lymphatic fluids. They range in length from microscopic species, such as *Microfilaria bancrofti*, to the extremely long guinea worm, *Filaria medinensis*, which probably averages 90 cm. in length. (Manson.)

B. *Microfilaria bancrofti* (*Filaria nocturna*). *Examine* a prepared slide of human blood taken from a patient suffering from elephantiasis, a disease caused by the presence of filariæ in the lymphatic vessels.

a. Under a moderately high power of the microscope, note that the filariæ have an eel-like form, with the anterior portion truncated, while the posterior portion gradually tapers off to a point.

b. Notice the clear *sheath* enclosing the entire worm. The mosquito, *Culex fatigans*, is the intermediary host for the species.

Draw the specimen.

C. *Examine* and *draw* filariæ in a blood smear from a ground-squirrel.

D. *Examine* specimens of *Filaria cervina*, a filarious worm inhabiting the peritoneum of cattle and other ruminants. Note the number of *papillæ* around the mouth, the number of *spicules* in the male, and whether the vulva of the female is anterior or posterior.

EXERCISE 30b

The Leeches

PHYLUM ANNELIDA, CLASS HIRUDINEA

A. *Characteristics of Annelida* (Annulata). Worms belonging to the Phylum Annelida consist of a series of rings or segments; there are no jointed appendages, the alimentary canal is well developed.

B. *Characteristics of Hirudinea.* The leeches are characterized by the possession of a sucker at each end of the body; the internal segmentation and the number of body rings do not correspond.

C. With a specimen of a leech before you, notice the following parts:

a. The *mouth*, situated in the *anterior sucker*.

b. The *anus* is located dorsal to the *posterior sucker*.

c. *Count* the number of *segments* or *annuli*.

d. *Examine* the buccal cavity of the specimen for jaws. What is the arrangement of the jaws? Some leeches do not possess jaws.

D. *Examine* a specimen of the medicinal leech, *Hirudo medicinalis*.

a. *Examine* the jaws for *teeth*.

b. What is the *color* of the specimen, noting longitudinal striping?

Draw the specimen.

E. If available *examine* and *describe* a specimen of the horse leech, *Hæmopis sanguisuga*.

EXERCISE 31

The Sheep Liver Fluke—Distomum Hepaticum

ORDER PLATYHELMINTHES, CLASS TREMATODA, ORDER MALACOCOTYLEA, FAMILY FASCIOLIDÆ

A. *Characteristics of Platyhelminthes.* Body more or less flattened dorso-ventrally; alimentary canal, absent entirely in the tapeworms, consists of a blind sac more or less branched. No anus. Usually hermaphroditic, and development in the parasitic species is usually indirect, i. e. through an intermediary host. The phylum is divided into three classes: 1, Turbellaria, free living, non-parasitic; 2, Trematoda, flukes; and 3, Cestoda, tapeworms.

B. *Characteristics of Trematoda.* Usually leaf-shaped, but in a few species conical; sucking discs are commonly found on the anterior and posterior extremities, and the ventral surface. Mouth is at anterior end, and sexual openings in the ventral sucker.

C. *Characteristics of Fasciolidæ.* One oral and one ventral sucker; excretory pore discharges at posterior border.

D. *Distomum* (*Fasciola*) *hepaticum.* This liver fluke in-

habits the bile ducts of such herbivorous animals as sheep, goats, deer and cattle. It is a cosmopolitan form, being found in North and South America, Europe, Asia, Australia and Africa. In many countries sheep raising is considerably hampered by liver rot caused by the presence of these parasites. The species undergoes a very characteristic complex metamorphosis, part of which is passed in the body of a snail of the genus Limnæus, and part in the herbivorous host.

Life history. The eggs are deposited by the hermaphroditic adult liver fluke in the bile ducts of the host, thence are washed out through these passages into the intestine and pass out of the host with the fæces. If the *ova* chance to reach water, the ciliated embryos, called *miracidia*, emerge. The miracidium soon penetrates the intermediary host, usually a small snail (Limnæus) entering through the pulmonary passage. Within the snail the miracidium transforms into the *sporocyst*, in which a number of bodies are formed, each of which develops into the next stage, the *redia*. Thus one egg may give rise to a number of individuals, through this sporulating process. The redia next develop into the tailed *cercaria*, in which condition the intermediary host is abandoned. The cercaria swim about in the water, finally losing the tail, and becoming encysted on a grass blade or other plant, which is eaten by the sheep or other herbivorous animal, resulting in infestation. In some species the cercaria bore into a second intermediary host, in which they become encysted and are swallowed by the animal together with this second intermediary host. Once within the alimentary canal of the final host the young flukes find their way to the bile ducts and reach sexual maturity.

E. *Structure.* With several specimens of the adult liver fluke before you, one of which should be stained and mounted in balsam, note the following characteristics:

a. *Form*, is leaf-like and flattened.

b. *Suckers*, with a hand lens note a terminal *oral sucker*, and a *ventral sucker*, whence the name Distomum.

c. *Sexual organs*, just back of the neck-like portion, in the region of the ventral sucker, notice the coiled *uterus*, yellowish in color, and filled with eggs. The *yolk reservoir* may be located just back of the uterus in the median line, as a dark colored more or less triangular organ, two ducts leading to it from the sides; these ducts in turn lead off to the finely branched *yolk glands*, seen as tiny dark spots on both sides of the body. The *ovary* is a definitely branched body lying to one side in front of the yolk reservoir. The ovary can be easily distinguished from the similarly branched *testes*, which are paired, by the fact that the latter occupy the greater part of the central area of the fluke. The ovary is usually darker and more compact. The *penis* and the *genital pore* are located within the area of the ventral sucker.

d. *Digestive system.* This consists of the *mouth*, located within the oral sucker, leading to a prominent *pharynx*, in turn leading to the bifurcated *intestine*, which lies along the lateral margins of the body, is much branched, and ends blindly.

e. *Excretory system.* The excretory system may be distinguished as a median light canal extending forward from the posterior end of the body.

Draw the specimen, indicating and *labelling* the parts seen.

F. *Examine* a portion of an infested liver, and notice the characteristic lesions produced by the fluke.

EXERCISE 32

Other Trematodes

A. *Dicrocœlium* (*Distomum*) *lanceolatum* is the lancet fluke of sheep and cattle. Examine several specimens of this species.

a. How does it differ in *size* from *Fasciola hepatica*?

b. Does the *form* of the fluke justify the specific name? *Describe* its form.

c. Locate the following parts, 1, *ventral sucker*, 2, *uterus*, 3, *intestinal branches*, 4, *ovarium*.

Draw a specimen, and *label* all the parts named in the preceding exercise that you can find.

B. *Examine* specimens of *Fasciola americana* (*Distomum magnum*) the giant fluke of cattle, infesting both the liver and lungs of the host. Compare these specimens with specimens of *Distomum hepaticum*, as to *size*, *shape*, *color*, absence in this species of *superficial spines*, etc.

C. *Paragonimus westermanni* is the lung fluke of man, occasionally found in other animals. This fluke is the cause of a *Hæmoptysis*.

a. What is the *form* and *size* of this fluke?

b. Locate 1, the *uterus*, 2, the *ovarium*, 3, two *testes*.

Draw the specimen.

D. *Schisostomum hæmatobium* (this fluke, unlike all the above, which are Distomidæ, belongs to the Family Schistosomidæ) is a Trematode producing *hæmaturia* or Bilharzia disease of humans.

Examine a specimen and *describe* it.

EXERCISE 33

The Tapeworms—A Morphological Study

PHYLUM PLATYHELMINTHES, CLASS CESTODA

The following tapeworm characters cannot well be studied without specimens of both the beef tapeworm, *Tænia saginata*, and the fish tapeworm, *Bothriocephalus latus*, or closely related genera, before you. Mounted and stained parts as well as unmounted specimens are needed.

A. *General.*

a. Tapeworms are more or less *ribbon-like* in *form*.

b. The head, or *scolex*, is at the tapering end of the worm, and is more or less globular.

c. Back of the head are the gradually broadening segments, or *proglottides*. The oldest proglottides are the farthest removed from the head, and these drop off most readily.

B. Under a compound microscope *examine* stained and mounted specimens of heads and proglottides from *Tænia saginata*, the beef tapeworm of man, and *Dibothriocephalus latus*, the fish tapeworm (closely related species will serve just as well).

a. *Head* of *Tænia saginata*. Notice the four cup-shaped *suckers*, and a projecting *rostellum*, on which there are no *hooks*.

b. *Head* of *Bothriocephalus latus*. Notice the presence of two groove- or slit-like *suckers;* the *rostellum* is absent.

c. A stained proglottid (not too mature) of *Tænia saginata* should show, 1, the *uterus* as a median-branched tube, tree-like in form, which extends nearly the entire length of the proglottis, 2, the *ovaries*, bilobed, finely branched bodies situated in the posterior end of the proglottis, uniting medianally with, 3, the *vitellogene gland*, situated along the median posterior border; 4, the *vagina*, a straight tube extending from the median posterior field to 5, the *genital pore*, on the median lateral border; 6, the *testes*, consisting of a large number of bodies distributed throughout the field as fine dots, and joined by 7, the *vas efferens*, which again connects with 8, the *vas deferens*, a coiled tube paralleling the vagina and also connecting with the genital pore, through 9, the *cirrus pouch;* 10, the *excretory system* may be seen as two transparent collecting tubes on either lateral border (four longitudinal tubes and a transverse connecting tube along the posterior border).

C. Compare with the above a stained proglottid of *Bothriocephalus latus*, the fish tapeworm already mentioned in B, as to form and position of the *uterus* and the position of the *genital pore*.

Draw a head and a proglottis of each species, *labelling* all the parts found.

EXERCISE 34

THE TAPEWORMS—A SYSTEMATIC STUDY

PHYLUM PLATYHELMINTHES, CLASS CESTODA

A. *Characteristics of Cestoda.* These flat-worms consist usually, in the adult form, of a small globular head or scolex, and a chain of segments called proglottides. In the adult stage they are parasitic in vertebrate animals, having the larval (bladder worm) stage in a secondary host, frequently invertebrate.

B. *Examine* specimens of the following species as far as available included in the two most important tapeworm families. The following list is only partial, and is meant to give the student merely a hint as to classification. Take notes on the specimens, with reference to characteristics.

a. Family *Bothriocephalidæ.* "Head provided with two groove- or slit-like suckers; rostellum wanting; uterus with special pore; genital pores generally (possibly always) dorsal or ventral." (Stiles.)

1. Genus *Bothriocephalus,* two elongate groove-like suckers present; the sexual pore opens in the mid-ventral region.

E. g. *Bothriocephalus latus,* the fish tapeworm of man, also found in dogs and other animals experimentally. May reach a length of 20 to 30 feet, with some 4000 proglottides. The middle proglottides are about three times as broad as long. The larva is a plerocercoid inhabiting the muscular system of certain fresh water fishes.

b. Family *Tæniidæ,* "Head with four cup-shaped suckers; rostellum present but not always evident; uterine pore wanting; genital pores generally marginal; body always segmented." (Stiles.)

1. Genus *Tænia,* scolex with a rostellum usually provided with hooks; mature proglottides longer than broad; genital

pores projecting at the lateral borders and alternating irregularly.

E. g. *Tænia solium*, the pork tapeworm of man. The rostellum is short and is provided with a double circle of hooks. The average length of the tapeworm is said to be from 8 to 12 feet, with 800 to 900 proglottides. The mature proglottides measure from "10 to 12 mm. in length by 5 to 6 mm. in breadth." (Braun.) The larva is *Cysticercus cellulosæ*, whose habitat is the connective tissue of swine.

2. Genus *Dipylidium*. "Rostellum retractile, armed with several transverse rows of alternating hooks; hooks with small roots, the base being discoidal; mature segments elongate with double sets of genital organs; pores double and opposite; ova with double transparent membranes." (Stiles.)

E. g. *Dipylidium caninum*, tapeworm of dogs, also found in cats, and occasionally in man, measures from 6 to 12 inches in length. The mature proglottides are about ¼ inch long by ½ inch wide, and have the form of cucumber seed, hence the synonym, *Tænia cucumerina*. The cysticercus of this tapeworm is found in the cat and dog flea, *Ctenocephalis canis*, and the biting dog louse, *Trichodectes latus*.

3. Genus *Drepanidotænia*. "Head provided with a single row of uniform hooks, few (8–20) in number, with dorsal root much longer than ventral root, the latter always small; with prong directed posteriorly when the rostellum contracts." (Stiles.)

E. g. *Drepanidotænia infundibuliformis* is a common tapeworm of poultry. This is described as follows: "20–130 mm., rarely 230 mm. long. Head globular, rather depressed; rostellum elongate, cylindrical or hemispherical, swollen at summit, armed with a single row of 16–20 hooks. . . . Suckers rather small. Neck very short; anterior segments very short, the following ones funnel-shaped, the anterior border being much narrower than the posterior border; posterior segments almost as long as broad; genital pores irregularly alternate." (Stiles.)

The cysticercus of this species is found in the common house-fly, *Musca domestica.*

Drawings should be made to illustrate the main characteristics of the above species of tapeworms

EXERCISE 35

Other Tapeworms

With the characters studied in the preceding exercises well in mind the student should examine carefully entire specimens in formalin (not slide mounts) of the following species, *taking notes* and *making drawings* such as are necessary to indicate the characters found.

a. *Tænia saginata* is the beef tapeworm (fat tapeworm) of humans, the cysticercus stage, *Cysticercus bovis*, being found in cattle.

b. *Monieza* (*Tænia*) *expansa* is the broad tapeworm of ruminants; the larval form is unknown.

c. *Tænia cœnurus* is a tapeworm inhabiting the intestine of the dog, wolf and coyote. While not dangerous to these hosts the larval form is the disastrous gid parasite of sheep.

d. *Tænia fimbriata* is the fringed liver tapeworm of sheep, a very injurious parasite of which the cysticercus stage is unknown.

e. *Tænia crassicollis* is the thick-necked tapeworm of the cat. The cysticercus stage is found in the liver of small rodents, such as rats and mice.

EXERCISE 36a

Larval Forms of Tapeworms

Larval tapeworms are known as *cysticerci* (cysticercus), *cœnuri* (cœnurus), or *echinococci* (echinococcus), depending on

the form of development at this stage. The cysticercus, or bladderworm, has a well-developed bladder, in which is found a retracted head bearing all the characteristics of the adult tapeworm head. The cœnurus, while inside of a bladder, like the above, develops a number of daughter cysts, with not more than one head in each, which is capable of developing into an adult tapeworm if ingested by a second host. The echinococcus develops a number of daughter cysts, inside of which there may be a number of heads. The echinococcus is ordinarily much more vesicular in form.

a. *Cysticercus cellulosa* is the larva of the pork tapeworm of man. *Examine* the cysticerci from the heart or voluntary muscles of a pig. Note the *size* of the object and determine the presence of a head.

b. *Cysticercus tenuicollis* is the diving bladderworm of the ox, and the larval form of *Tænia marginata* of the dog. It is one of the largest bladderworms, often an inch and a half or more in diameter. The long, slender, invaginated head can be seen through the tissue. *Examine* some bladderworms from the peritoneum of cattle.

c. *Multiceps multiceps* (*Cœnurus cerebralis*) is a larval tapeworm found in the brain and nerve cord of the sheep, causing the disease known as *gid*. *Examine* a specimen of this cœnurus, noting the number of heads and the characteristics of the same.

d. *Echinococcus multilocularis* is found in man, cattle and swine, and is the larval form of a tiny tapeworm found in dogs. The echinococcus is found primarily in the liver, but may attack other organs. Here the original cyst develops many daughter cysts, forming an alveolar structure, often of considerable size. *Examine* a section of human liver affected with echinococcus.

Drawings of the above types should be made.

EXERCISE 36b

Helminth Ova

In studying the characteristics of Helminth eggs the following from Manson's "Tropical Diseases" is suggestive: "The points to be attended to in the diagnosis of ova are *size*, *shape*, *color*, *thickness*, *roughness*, *smoothness* and *markings* on the surface of the shell; the presence or otherwise of yolk spheres, of a differentiated embryo, or in the case of the cestodes, of the three pairs of embryonic hooklets; the existence of an operculum in the case of certain trematodes and of the broad tapeworm (Dibothriocephalus). The ova of the same species of parasites vary but slightly, and are in every instance stable and definite for correct diagnosis."

With the above in mind, study, *describe* and *draw* the following species of ova:

a. *Strongylus ovis pulmonis*, the lungworm of sheep.

b. *Trichocephalus trichuris*, the whipworm of man.

c. *Necator americanus*, the American hookworm of man.

d. *Ascaris lumbricoides*, the roundworm of man and swine.

e. *Fasciola hepatica*, the sheep liver fluke.

f. *Schisostomum* (*Bilharzia*) *hæmatobium*, a trematode of humans which produces hæmaturia.

g. *Tænia solium*, the pork tapeworm of man.

EXERCISE 37

Insect Larvæ

This exercise is to give the student facility in distinguishing insect larvæ from worms, an important matter when it is necessary to trace modes of infection and to administer remedial measures.

The following examples of insect larvæ should be studied carefully, *counting* the number of body segments, noting the presence or absence of special prehensile hooklets, and other external characteristics. *Draw* a specimen of each.

A. Types of insect larvæ.

a. Larvæ of the horse botfly, *Gastrophilus equi;* habitat, stomach of equine animals.

b. Larva of the ox warble-fly, *Hypoderma lineata*, causing what is commonly called "grub in the back" or warbles; habitat, the deeper layers of the skin of bovine animals.

c. Larva of the head maggot fly, *Œstrus ovis;* habitat, nasal sinuses of sheep and deer.

d. Larva of the warble-fly of rabbits, *Cuterebra cuniculi;* habitat, deeper layers of the skin of rabbits and other rodents, commonly found in the neck.

e. Larva of the screw worm fly, *Chrysomyia macellaria;* which is commonly found in wounds and open sores of domesticated animals.

f. Larva of the common blowfly, *Calliphora vomitoria*, a flesh fly and scavenger.

g. Larva of the common housefly, *Musca domestica.*

B. *Examine* a dissection of a fly larva under both low and high power objectives, noting the *tracheal* system, an intricate series of tubules ramifying through all parts of the body. *Draw* several tracheæ.

C. Describe points of difference noted between worms and larvæ.

EXERCISE 38

Anthelmintics

While the main object in the present work is to prevent infection, the student should nevertheless be familiar with the commoner agents used to destroy and expel internal parasitic worms.

Owing to possible complications not foreseen by anyone but an experienced physician or veterinarian, the use of anthelminthics is not recommended except under proper prescription. Care should also be used in handling such materials. A description of samples may be made, based on whether the material is liquid or solid, its color, odor and other obvious characteristics.

A. *Anthelminthics for Humans.*

a. *Pumpkin* or *Melon seeds* are useful when eaten fresh in half-ounce or ounce doses, as a preparatory remedy to further treatment for tapeworms.

b. *Male Fern* (Aspidium) is used in the oleoresin form (*Oleoresina aspidii*) against tapeworms. This is dangerous unless properly used.

c. *Levant wormseed* (Santonica) was formerly used, but has been largely superseded by (d).

d. *Santonin* (Santoninum) is one of the best remedies against roundworms (Ascarids).

e. *Turpentine* is used in diluted form as a rectal wash against pinworms (Oxyuris).

f. *Thymol* has been found very useful in treating uncinariasis (*Necator americana* and *Ankylostoma duodenale*).

g. *Pomegranate* (Granatum) produces a volatile alkaloid, Pelletierin, which is useful for tapeworm.

B. *Anthelminthics for Domesticated Animals.*

a. *Areca nut* (fruit of *Arecha catechu*) is commonly used in veterinary medicine as an anthelminthic, either alone or together with some other ingredient, against intestinal worms, such as roundworms and tapeworms.

b. *Sulphate of iron* either alone or together with some other ingredient such as arsenious acid is useful for roundworms in horses.

c. *Arsenious acid* is used in connection with sulphate of iron for roundworms.

d. *Oil of turpentine*, doses with milk (1 to 16 parts) dose 2 to 4 ounces against bots and other stomach worms.

e. *Common salt*, *powdered ginger* and *saltpetre* are used together in warm water against stomach worms.

f. *Tartar emetic* given repeatedly is a remedy recommended for roundworms in horses and cattle.

g. *Kamala* is an agent used in treating cattle for roundworms (Ascarids).

PART III

LIFE-HISTORY STUDIES ON LIVING PARASITES

INTRODUCTION

The work in the laboratory is made very much more interesting and profitable if the student has the opportunity of making observations on living animals. Courses opening in the first semester come early enough in the year to make it possible for the student to collect his own material out-of-doors. For courses beginning in the second semester the instructor is cautioned to collect material in the autumn and continue breeding through the winter. This is possible for at least some of the required material. Furthermore, spring usually opens up early enough so that living material can be secured after the course begins, and in time to make observations on the same. It is advisable to have either a special breeding room or a part of the main laboratory set aside for this purpose.

By doing these exercises the student secures a knowledge of habitat and behavior that will be of great assistance to him in practical field work, and the impressions thus secured will be lasting.

How to Proceed. The student must secure his own material, either by securing the fully mature specimens (male and female) and providing the conditions under which eggs are deposited, a matter not so easily accomplished in all cases, or by securing the eggs in the field under natural conditions, which plan is recommended. Breeding jars can easily be constructed of pint fruit jars or smaller sized glasses, covered over with fine-mesh bobbinet, gauze or filter paper.

Since this work will go on through the greater portion of the semester the student is expected to collect his specimens early in the course and make observations from time to time to ascertain developments. This can be done at the opening of each laboratory period or oftener.

For notes the same sized paper is to be used as for the exercises requiring drawings. The exercise is to be given its regular number and title. The date of collection should be indicated, together with place and conditions. Each day observations are made the date should be set down, together with memoranda as to progress in life history, continuing thus until the organism has matured or the term has closed. If the specimens die, more should be collected.

EXERCISE 39

Life History of the Common Housefly

A. The student will collect two or three dozen or more of housefly eggs. These can be collected, either from neighboring horse-manure piles, or adult flies may be captured and placed in a breeding cage into which is put also a jar of horse-manure.

B. Place the eggs into a jar which is partly filled with horse-manure. The jar should be kept in a warm room. Cover the jar with gauze or bobbinet.

C. Observe the date on which the larvæ hatch from the eggs. You will now have the *incubation period.*

D. Note the date on which feeding ceases and full growth has been reached. You will now have the period of *growth.*

E. After the larvæ cease feeding they usually try to leave the manure, crawling into drier portions or nearby debris and prepare to pupate. This is called the *prepupal period.*

F. Observe the date of *pupation.*

G. After a given number of days in the pupal stage the fly emerges; it is now an *imago.* If the fly is to live the student

must provide a dish of water, which may be sweetened with sugar.

H. Several days must elapse before the fly is sexually *mature*, when *copulation* occurs, and the females shortly thereafter deposit eggs.

I. Data on the length of life of any animal is valuable, so that the student should endeavor to keep the flies alive as long as possible, noting the time of death.

J. Flies as carriers of bacteria.

a. Collect half a dozen houseflies out of doors, noting the immediate environment and sex of the individuals. The flies must be collected in sterile vials.

b. Prepare six sterile agar plates.

c. Place the agar plates under sterile bell-jars and liberate one fly for each plate and wait until the flies have crawled about on the agar.

d. Note the condition of the agar. Can you see any tracks that the flies have made?

e. Place the agar plates in a bacteriological incubator and incubate for 36 hours.

f. What changes have taken place, and what are your conclusions?

EXERCISE 40

Life History of the Mosquito

A. Collect several egg rafts of a common Culicine mosquito. There are usually pools of standing water, or nearby horse-troughs, on the surface of which the egg rafts can easily be seen. Count the number of eggs in one of the rafts.

B. Place the eggs in a pint fruit jar, partly filled with water taken from the original pool.

C. Note the date when the larvæ (*wrigglers*) emerge.

D. Change the water in the jar from time to time by drawing

out the old water and adding fresh, using water from the original source if possible.

E. Observe the feeding and breathing habits of the wrigglers.

F. Take several of the wrigglers from the jar and place them in another jar of water. Then add a few drops of kerosene. Note the behavior of the insects.

G. Observe the dates when the wrigglers cast their skins (moult).

H. After a given number of days the pupal (*tumbler*) stage is reached. Observe breathing methods.

I. If you wish to save the mosquitoes you must now cover the jars with a screen, or preferably a glass funnel, which can be plugged up, and permits one to capture the mosquitoes more readily.

J. Transfer the mosquitoes to a breeding cage provided with a dish of water. After allowing the female mosquitoes to have a suck of blood, note the date of egg deposition.

EXERCISE 41

Life History of a Flea

A. Collect specimens of fleas from a dog and place the fleas in a glass vial covered with gauze. The females usually deposit eggs very readily.

B. After several days the flea larvæ will emerge. You must now add some moist sawdust and fecal material from rodents, or dry blood. The vials must be kept in a warm place, otherwise growth is exceedingly slow.

C. If possible follow the growth of the flea larva to the time when it spins a cocoon and pupates.

D. Pupæ can be kept under observation more readily. Note the date when the flea emerges.

THE following pages contain advertisements of books by the same author or on kindred subjects

Malaria, Cause and Control

BY

WILLIAM B. HERMS, M. A.

Assistant Professor of Applied Parasitology, University of California; Officer in Charge of Malaria Investigations California State Board of Health; Author of "How to Control Mosquitoes with Special Reference to Anopheles," "Protecting California's Health Resources through the Control of Disease-Bearing Insects," "The Housefly in its Relation to Public Health," etc., etc.

Cloth, Illustrated, 8vo., $1.50 net; postpaid, $1.63

The awakening of the general public to the necessity and possibility of the control of Malaria, indicated by the incessant demand for information, makes the publication of Professor Herms's concise treatment of the subject an important and timely event. The question of Malaria control is deserving of the most careful attention, particularly in these days when so much is heard of the "back to the soil" movement. For malaria is notably a disease of rural districts. Those who are familiar with the situation know very well that malaria is too often responsible for farm desertion. Professor Herms writes of the conditions attending the disease as he has found and studied them during the past few years himself, and the suggestions for control which he makes are such as he applied with success.

The book contains many illustrations that show in an interesting fashion the methods of prevention.

"Nowhere have we found in a single volume so practical a description of the different phases of the malarian protozoön, the anatomy of the mosquito and the distinctive characters of the different groups of the mosquito family."

—*Chicago Evening Post.*

"The author has given us in clear and simple language, many helpful facts."—*Boston Globe.*

"The book is well illustrated, the pictures of mosquitoes and of various methods of combating the mosquito being particularly illuminating."—*Philadelphia North American.*

THE MACMILLAN COMPANY

Publishers 64-66 Fifth Avenue New York

Household Bacteriology

BY

ESTELLE D. BUCHANAN, M.S.

Recently Assistant Professor of Botany, Iowa State College

AND

ROBERT EARLE BUCHANAN, PH.D.

Professor of Bacteriology, Iowa State College, and
Bacteriologist of the Iowa Agricultural Experiment Station

Cloth, 8vo., XV+536pp., index, $2.25 net

The word Household is used as an extension rather than a limitation of the title. In a thoroughly scientific manner the authors treat the subject-matter of general as well as of household bacteriology and include, therefore, the true bacteria as well as the yeasts, molds and protozoa. The volume is, therefore, a general textbook of micro-biology in which special attention is given to those problems which are of particular interest to the student of household science. The main divisions of the book treat (1) the micro-organisms themselves, (2) fermentations with special reference to those affecting foods, (3) the relations of bacteria and other micro-organisms to health. A fully illustrated key (comprising 37 pages) to the families and genera of common molds, supplements the unusually extended discussion of the morphology and classification of yeasts and molds, and makes possible the satisfactory identification of all forms ordinarily encountered by the student. The work embodies the results of the most recent researches. The book is exceptionally well written, the different topics are treated consistently and with a good sense of proportion. While concise in statement, it is thorough in method and scope. It is, therefore, well adapted for use as a text not only *for students of household science*, but *also* for those to whom it is desired to present the science of bacteriology from *an economic and sanitary rather than from a strictly medical point of view.*

"The book is a concisely written work on microbiology, a branch of economic science that the public is beginning gradually to understand, has important relationship to the total welfare and prosperity of the community. . . . The manual can be recommended as a very good elementary bacteriology. It comprises about all there is of practical domestic value."
—*Boston Advertiser.*

PUBLISHED BY
THE MACMILLAN COMPANY
Publishers 64-66 Fifth Avenue New York

Manual of Bacteriology

BY

ROBERT MUIR, M.A., M.D., F.R.C.P., ED.,

Professor of Pathology, University of Glasgow

AND

JAMES RITCHIE, M.A., M.D., B.Sc.,

Reader in Pathology, University of Oxford

New American Edition *Revised and Enlarged* *$3.25 net*

"The American edition of this well-known manual is perhaps one of the best and most comprehensive, up-to-date handbooks for the student published in the English language. The treatment of the doubtful questions is to be commended. The investigations of each observer and the conclusions are stated with as little bias as possible. . . . An appendix furnishes a compact outline of the principal literature on the different subjects. This outline deals chiefly with the original works found in the foreign languages."—*Medical Record.*

"Like Gray's Anatomy, Green's Pathology, Parkes's Hygiene, and other classical text-books, this manual is destined to remain for years to come the favorite of both teacher and student, to whose needs it is so admirably adapted."

—*Philadelphia Medical Journal.*

"A very useful work for the purpose intended."

—*International Medical Magazine.*

PUBLISHED BY

THE MACMILLAN COMPANY

Publishers **64-66 Fifth Avenue** **New York**